Popular Astronomy

Vol. XLV, No. 4 APRIL, 1937 Whole No. 444

The New Universe*

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If you've ever pitched camp in the Southwest desert lands and spent a night alone beneath the starlit sky, or if you've stood a lone watch during the long night hours on the deck of some little vessel hundreds of miles from land with nothing but the stars above and the seas beneath, I would venture to say you have caught a certain awareness of the universe around us not found by others who have never made such lonely ventures from the more conventional routine of human existence. One can, of course, see the stars from almost any locality. The distraction of neon signs, highway flood-lights, and social companions, no matter how delightful, robs one, however, of that vital sense which comes when one is alone with the stars.

I remember as a youngster, first fascinated with the lure of the sky, stealing away from home just before sundown to spend the night on a neighboring hill-top in order to watch the panorama of the skies from sundown to sunrise to get a glimpse of the drama of creation as enacted before primitive man who knew nothing of the wonders of modern science and had to make of the universe around him what his untutored intelligence would allow. Fortunately with the ingenuity of science and invention, it has become possible for city dwellers to catch a realistic picture of the night-time sky in miniature in any of the several planetaria of which each of several American cities can boast one. Those of you who may have visited the Hayden Planetarium in New York City, the Fels Planetarium in Philadelphia, the Adler Planetarium in Chicago, or the Griffith Planetarium in Los Angeles have probably not failed to note the element of awe and surprise unconsciously expressed by the audience when the lights in the lecture hall are extinguished and the overarching dome suddenly bursts into view with a very realistic starlit sky.

Years have brought about vast changes in the world about us. Buildings of yesterday have been replaced by modern skyscrapers. City apartments have crowded dwellings to the suburbs. Concrete highways replace country roads and wooded lanes. The habits of men have changed. Society and politics are moving at a rapid pace. Yet, did you ever stop to think that the sky is overhead and is the same, that its planets and the sun and the moon are the same as they were centuries ago when the early watchers of the sky, somewhere in the Mesopotamian valley, began to study the positions and the movements of the stars in

*Address presented as first of a series on "Recent Developments in Science," at the Springfield (Massachusetts) Public Forum, February 16, 1937. Printed also in the "Tech Engineering News."

order that they might bring order out of chaos in the universe in which we live? Of course the universe is changing. Stars rush hither and yon at incredible speeds but the distances of these celestial objects are so great that, so far as any visible change is concerned, a thousand years are as yesterday when they have passed. What the universe really is, how it came about, and why there should be any universe at all are problems for a philosopher, and he will never answer them. Such questions, however, are so intriguing and so persistent that man has never been content not to know more about the universe around him. His own life and mode of existence have undergone some vast changes as the result of his changing ideas of the universe in which he lives. One is perhaps all too accustomed to think of the sky as something far removed from the earth. I remember a freshman who once wished to enroll in a course in astronomy because he was advised while he was in college to take some subject which never would have anything to do with anything that might concern his subsequent career, and he thought astronomy might fill this requirement admirably. On the other hand, modern astronomy tells us that we inhabit the surface of a tiny planet revolving about a second or third rate sun which is but one of many billions comprising our so-called galactic system. If, through some magic trick, we were to make the earth disappear, we should find ourselves veritably in the midst of the stars. We should need to change our position only slightly, as astronomical distances go, and we should find ourselves so far removed from the sun that it in turn would appear but a scintillating point of light lost among the myriads of stars all around it. The distance from the sun to its closest neighbors is not very different from the distance separating any two stars at random that we might pick out of the bewildering throng. Under such strange circumstances we should be bewildered as to any sense of direction. With the earth gone, there is no north, south, east, or west, for these are directions referred to gravity drawing all things to the center of the planet on which we travel. Without the earth, however, life itself could not exist, so perhaps we had better withdraw from our imaginative picture to find ourselves comfortably stationed aboard this planet providing air, water, and a congenial environment on which life itself depends. Even so, while in reality stationed on this planet Earth, we are in a very real way aboard an interspatial ship. Our problem of surveying the universe around us is somewhat complicated by the motions of this ship on which we find ourselves. Rotating on its axis once every day, we in the middle latitudes are being carried by the movement towards a certain region of the sky at a speed of some 600 miles an hour due to the velocity of the earth's rotation. Meanwhile, the earth is revolving about the sun. As we partake of the earth's orbital motion we are being carried at a speed of 18½ miles a second towards one direction in the sky this spring, and we will be going in the opposite direction next fall. The sun, a typical star which is dictator in the affairs of the solar system, is journeying toward

the bright star Vega at a velocity of some 12 miles a second or 400 million miles every year. To paraphrase the words of another, "We are on our way," even if we do not know where we are going. Recent studies of the motions of the stars indicate that the whole galaxy of suns is rotating about a common center at such a speed as would carry us through one revolution in perhaps two or three hundred million years. Investigations of the age of the earth tell us that the planet on which we live is probably some two billion years old, so perhaps it is a bit consoling to know that the earth has survived at least several rounds of the galactic system during its ephemeral career.

Far beyond this galaxy of ours are the spiral nebulae, other galaxies of stars at distances so remote that observations of them in our telescope tonight tell us not where they are, but where they were, a million, ten million, or a hundred million years ago. Meanwhile, the axis about which the earth is spinning does not preserve a constant direction in space. It gyrates like the axis of a spinning top as it is pulled this way and that way by the gravitational forces of the sun and moon. Recent investigations clearly indicate that even the crust of the earth is less stable than we thought, so that perhaps our observations of the stars are made as though from a floating ice cake, lifting and falling a minute amount as tides in the solid earth surge beneath our feet. All these motions are reflected in the motions of the stars, and have to be disentangled before man can understand very much about the true movements of the stars themselves. No such complicated picture of creation presented itself to primitive man. He took the universe that he saw with his eyes very much at its face value. To him the stars were but luminous points apparently fixed on the inside of a hollow sphere which turned smoothly about the earth. Then, too, within this revolving dome the sun and moon and seven wandering stars—the planets—were seen to trace their movements against the background of the sky.

It is perhaps not surprising that man's first interest in studying the stars was a personal one. Knowing nothing of the true nature or the remote distances of these celestial objects, he saw them as embodied spirits influencing his affairs from day to day and year to year. Fortunate and unfortunate events were clocked by the aspects of the heavens. To protect the future course of his fortune, therefore, he must learn to decipher the movements of these celestial objects so that he might foretell the reoccurrence of certain aspects of the sky, which coincided with significant events in the bitter experience of mankind. The early astronomers were astrologers. Not until the Renaissance and the invention of the telescope began to show the true nature of the heavens did the superstitions of favorable and unfavorable aspects among the planets give way to enlightened study of the heavens that should discover truth for truth's sake, irrespective of any personalized application.

The universe of yesterday was a geocentric one. Since no matter in which direction man looked, distances in the sky all appeared the same,

the earth was naturally thought to be the center of creation. Since one experiences no sense of movement as the earth rotates and revolves about the sun, it was indeed natural that the earth should be regarded as a fixed body in a geocentric system. Only through the complication of cycles and epicycles in explaining planetary motion were the early astronomers led to the belief that the earth itself was a roving planet revolving about the sun once a year, and that the sky appeared to turn once daily about the earth because of the rotation of the earth on its axis.

The champion of this new astronomy was Copernicus, who in 1543 published his revolutionary epoch-making book, "De Revolutionibus Orbium Celestium," in which he set up a system of astronomy with the sun at the center of the universe, the earth taking its place among the other known planets, Mercury, Venus, Mars, Jupiter, and Saturn, which revolved about the sun. The book brought a storm of protest. For 1500 years men had come to believe in the simple picture of creation consistent with a mediaeval theology. So closely entwined were theological conceptions with a naive picture of creation that to alter the science of that day meant also the wreckage of theological doctrine. Copernicus died as the storm clouds gathered. Storms of controversy ensued, the reverberations of which lasted for nearly three centuries.

The transition from the geocentric system of mediaeval cosmology to the Copernican doctrine of a centralized solar system with the stars in the background presented the beginnings of a new era—a new conception of the universe. This was an era in astronomy concerned chiefly with the problems of untangling the puzzling riddles presented by our own planetary system. In providing the necessary data on which a true picture of the new order must rest, Tycho Brahe, a Danish astronomer, stands out as an immortal pioneer. With the true spirit of scientific adventure, he began to improve instruments and to make painstaking and systematic observations of the stars and planets in order that he or his successors might put to the test the relative merits of the geocentric and heliocentric astronomy in establishing the theory of planetary motions. Tycho's own opinions in regard to the outcome are of little concern. He proposed a compromise theory that still held the earth in the center of the universe, thus setting aside the theology of those whose conceit demanded man as the focus of the attention of the Almighty and the purpose for which creation had come to be. Then he let the sun revolve about the earth and be the center about which all the planets except the earth revolved. His theory gathered little following but the observations which he made were the foundation material upon which Johann Kepler, an assistant of Tycho Brahe's, was able to announce three important laws of planetary motion: (1) that all the planets including the earth revolved about the sun in ellipses with the sun at one of the foci; (2) that the variable motion of the planets in these elliptical orbits followed a definite law which could be described by stating that lines joining the planets and the sun swept over equal areas in equal times as the

planets pursued their circumsolar journeys; (3) that there was a certain harmony in the interrelationships of the distances and the periods of revolutions of the several planets which could be mathematically described by saying that the squares of the times of revolution were proportional to the cubes of the mean distances of the planets from the sun. As Kepler stated them, these were but empirical laws. They mark, however, an important milestone in the journey to the complete solution of planetary theory. For it was upon these laws that Newton was to develop his theory of universal gravitation and to sense that planets were held to the sun by an invisible force which varied inversely as the square of the distance. Newton was able to demonstrate his hypothesis by clocking motions of the moon and showing that the moon revolving about the earth as a center performed exactly in accordance with this law. When applied to the motions of the planets about the sun, he showed that his conception of a gravitational law could be used as a basis for proving each of Kepler's three laws. With the publication of his complete theory of gravitation and the celebrated *Principia,* the mysteries of planetary motion were brought to a successful solution in the early part of the eighteenth century. The extension of the gravitational concept to a law of universal application as was embodied in Newton's statement that "every body in the universe attracted every other body with a force proportional to the product of the masses and varying inversely with the square of the distance between their centers," was a great adventure of the imagination. This adventure was completely justified when Sir William Herschel in the latter part of the eighteenth century demonstrated the existence of gravitational systems among the stars themselves. In search for periodical motions among the brighter stars with respect to close companions, Herschel found that in the case of many of the so-called double stars, the fainter of the two objects were revolving about the primary star in such a manner as to indicate motion in an ellipse. This was a factual demonstration of the law of gravitation amongst stellar systems.

As Copernicus stood on the threshold between the old order and the new, while opinions slowly moulded themselves from the geocentric picture of the universe to the heliocentric picture of the newer astronomy, so Sir William Herschel stands as a transition between the pretelescopic era in astronomy, concerned chiefly with planetary motions, and the telescopic era which has gone far beyond the solar system into the outer regions of stellar astronomy.

The telescope, whose origin as an optical instrument is still obscure, was first applied to astronomy by Galileo, who in 1610 startled the mediaeval philosophers with his discovery of four moons revolving about the planet Jupiter, a ring about the planet Saturn, spots on the supposedly immaculate sun, and the demonstration that the planet Venus exhibited all the phases of the moon, thus showing that it shone by a reflected light from the sun. Galileo's little telescope revealed unnumbered

stars invisible to the naked eye, showing that creation was far more extensive than the simple picture presented to the eye of man without optical aid.

The advances in the construction of telescopes due to the ingenuity and painstaking workmanship of Sir William Herschel are no less than astounding. It was Herschel who developed and perfected the reflecting type of telescope that is the model for our largest instruments today. By 1789 he had succeeded in completing an instrument four feet in diameter which was not exceeded until 1845 by a six-foot instrument constructed by Lord Ross at Parsontown, Ireland. Such an instrument was not again equalled until the 72-inch telescope was installed in the Dominion Astrophysical Observatory at Victoria, British Columbia, in 1916.

It was particularly significant that in linking the era of planetary astronomy with that of stellar astronomy, Herschel should have made notable contributions in both fields. In 1781 he discovered the planet Uranus, a large planet revolving far outside the orbit of the planet Saturn, the outermost known of the classical planetary systems. The discovery of Uranus not only extended the boundaries of the solar system as the result of telescopic observations, but it later proved to be an important link by means of which in 1846 the planet Neptune was discovered. The discovery of Neptune was in itself a triumph for gravitational astronomy. Soon after Herschel had discovered the planet Uranus, it was found that its motions failed to confirm strictly to that predicted on Newton's gravitational hypothesis. Before the middle of the nineteenth century, the accumulation of discrepancies in its motion made possible two assumptions: (1) that Newton's gravitational theory did not work at distances out beyond Saturn or (2) that the peculiar and erratic motions of Uranus were due to the attraction of an unknown planet lying out beyond, the position of which, because of this very law of gravitation, was indicated by the movements of Uranus itself. On this second hypothesis, two brilliant mathematicians, Adams, an Englishman, and Leverrier in France, calculated the probable position of such an hypothetical planet. So close in agreement were the results of these independent mathematicians that the German astronomer Galle was enabled to turn his telescope to the region of the sky suggested by the calculations and within half an hour and within a moon's breadth of the predicted place find the planet Neptune, thus making memorable in astronomical annals the night of September 12, 1846.

Leaving to others such planetary problems as might still exist, the pioneer spirit of Herschel pushed forward into stellar realms. Night after night, year after year, with telescopes of increasing power, made with his own hands, Herschel penetrated the Milky Way, painstakingly counting the stars that swept through the field of his telescope, until by taking samplings here and there he built for himself a picture of what the universe of stars might really be like. His star counts revealed that

the bulk of stellar systems lay in the general plane of the Milky Way. At right angles to this plane stars were relatively sparse. He pictured to himself, therefore, that the universe of stars must be shaped something like a crudely hewn grindstone with the sun and earth not far from the central plane. When we look out in the direction of the axis of the grindstone, we therefore see relatively few stars, and increases in telescopic power added little to the stellar population in these directions. Looking towards the periphery of the grindstone from our central position, we were looking through the long dimension of the universe. Thus stars crowded in countless numbers in the field of his telescope as he swept it along the Milky Way, reminding one of those lines of the immortal Milton:

> "A broad and ample road
> Whose dust is gold and pavement stars,
> As stars to thee appear seen in the Galaxy,
> That Milky Way that nightly
> As a circling zone thou see'st powdered with stars."

While surveying the Milky Way, he was astounded with dark areas where scarcely any stars appear at all. It seemed to him that they were windows through which he looked into the blackness of the void beyond the stars. On finding one of these black holes in the constellation of Scorpio, Herschel is said to have exclaimed, "Hier ist verhaftig ein Loch im Himmel!" The study of these dark areas by our modern instruments has convinced us that in place of empty space through which we look into the void beyond, these dark areas in the Milky Way represent vast patches of obscuring matter between us and stars in the galactic background. It is truly surprising, however, that Herschel's conception in making a picture of the universe should be so nearly in accord with that revealed today by telescopic observations.

In his extensive survey of the heavens, Herschel discovered thousands of patches of a nebulous character faintly luminous even in his large instruments,—the so-called nebulae. Only two of these are bright enough to be glimpsed by the naked eye at all,—the great nebula in the sword of Orion scintillating in the South during winter evenings, and another known as the great nebula in Andromeda not far from the familiar constellation of Cassiopeia's Chair (Plate II). It so happens that these two nebulae represent what we know today to be of contrasting types. The great nebula of Orion is a mass of glowing gas made luminous most probably by the excitation of the radiation from neighboring stars. Its distance is not great as distances to nebulae are reckoned, for it is well within our own galactic system, and rather a close galactic neighbor at that. The great nebula in Andromeda which appears as an elliptical patch in a telescope of moderate power is an aggregation of stars, or suns like ours, so far away that it takes light nearly a million years to reach us after it has left that distant system. Such an enormous distance places it far beyond the most generous limits that modern astronomy will allow for our galaxy. If we regard our galaxy of stars as our uni-

verse, then the Andromeda nebula in this sense is indeed another universe by itself. It is one of perhaps a million such objects, most of which are many times farther away and appear to be wisps of light in our greatest telescope. These are the extra-galactic nebulae.

It was quite impossible, however, for Herschel to distinguish analytically between the characteristics of these contrasting types of nebulae. Any fuzzy object which in his telescope would not be resolved into independent stars was quite likely assigned to the general class of nebulae. With his bigger and better instruments he began to discover that many of these nebulous patches of light could be resolved into independent clusters of stars, many of which were globular in shape. Could it be, thought Herschel, that were it possible to build telescopes big enough and powerful enough, all of these faint nebulae might be resolved into aggregations of stars? Herschel could ask the question but he could not answer it, for means were not yet at his command to settle the query. Not until the invention of the spectroscope and its application to astronomy, making possible the analysis of starlight, could the difference between the Orion nebula and the Andromeda nebula be delineated.

It was in the year 1859, the very year in which Darwin published his "Origin of the Species," which revolutionized biological thought, that the spectroscope was fairly introduced into astronomy. Newton in his optical researches had passed sunlight through a triangular glass prism and broken it up into all the colors of the spectrum, but because of failing to interpose a narrow slit in the light beam, Newton failed to discover the significant "lines" in the spectrum, which gave birth to the new science of astrophysics. As is well known by every laboratory worker, a fine slit interposed between the sun and the optical system of a spectroscope will produce a spectrum crossed with faint dark lines, each line occupying a definite position in the frequency scale of light characteristic of the state of ionization of the atoms of chemical elements in the atmosphere of the sun. When light from the interior of the sun or other star passes through an atmosphere of hydrogen gas, for example, this gaseous envelope will subtract from the entire spectrum the particular frequencies that incandescent hydrogen would produce. The characteristic dark lines or vacancies, thus appearing in the resulting spectrum, proclaim the presence of a hydrogen envelope. The discovery of these laws of spectrum analysis underlying this principle may be attributed to Kirchoff who announced them in the year 1859.

It was Sir William Huggins who first turned the spectroscope towards a little nebula in the constellation of Draco and saw there not the familiar absorption spectrum so characteristic of stars, but an emission spectrum consisting of isolated bright lines that betrayed the existence of incandescent gas in the faint nebula. The Orion nebula betrayed itself likewise through the existence of isolated bright lines. The nebula of Andromeda reveals, on the other hand, a continuous spectrum crossed by dark lines like that of the stars. Thus Huggins by the application of

the spectroscope to the telescope was able to answer Herschel's question. Some nebulae are aggregations of stars; whereas others are but diffuse clouds of luminous gas. The classification of the nebulae began.

The application of the spectroscope to the analysis of starlight revealed myriad patterns of spectra and made possible the beginnings of the vast classification of stars into an evolutionary sequence. Thus, as a result of the introduction of the spectroscope into astronomy about 1859, a program of inorganic evolution could be prospected just as in the same year the publication of the "Origin of the Species" was a prospectus of an evolutionary theory in the biological or organic world.

By the close of the 19th century and the beginning of the 20th, the new astronomy, or astrophysics, was attaining a healthy growth. The establishment of new observatories in America, equipped in anticipation of the emphasis which would be placed upon the spectroscope in the era of astronomy, gave the United States a fair lead in this new field.

The Yerkes Observatory of the University of Chicago, founded and first directed by Dr. George Ellery Hale on the shores of Lake Geneva in Wisconsin, startled the astronomical world with its new and powerful telescopic and spectroscopic equipment. A refracting telescope with a lens 40 inches in diameter, the largest lens that has ever yet been put into commission, equipped with solar and stellar spectrographs, began in earnest a systematic analysis of sunlight and starlight. Dr. Hale's newly invented spectroheliograph made possible the photography of the sun in the light of some one element alone in the solar atmosphere. Thus it became possible to take photographs of the sun in the light of calcium or hydrogen and to find as a result that vast clouds of calcium and hydrogen gases known as flocculi flitted over the sun's surface from pole to pole and congregated in vortices about the disturbed centers where sunspots had been seen. A temperature controlled spectrograph especially designed for photographing the spectra of the stars made possible an extensive study of the motions of the stars towards and away from the earth.

Just as the pitch of a locomotive whistle rises as the train approaches an observer and falls as it recedes, so the pitch in the particular note struck by light waves from hydrogen gas or from helium or from any other element is slightly higher than normal if the star is approaching the earth, and slightly lower than normal if the star is receding from the earth. By measuring the distorted position of the lines in the spectra of the stars one can calculate not only the change in pitch but the very velocity at which the star is approaching or receding from the earth. This is the well-known Doppler-Fizeau principle. In the days of Herschel one had to wait decades and often centuries to discover that the fixed stars were slowly changing their positions in respect to each other. With the spectroscope, on the other hand, a single night's observations revealed stars coming towards us, and stars going away from us, and the actual speeds of their motion in the line of sight.

So successful were the new departures in solar and stellar physics established by Dr. Hale at the Yerkes Observatory that a substantial appropriation was made by the newly-created Carnegie Institution of Washington for the establishment of a new observatory at Mount Wilson, California, under Dr. Hale's direction. Here, midst vastly improved atmospheric conditions, began the building of the most extensive observatory equipment that the world has ever known, reaching its climax in the construction of a 200-inch reflecting telescope now in the process of manufacture for Mount Palomar, California. It is significant that in the establishment of telescopic equipment on this new mountain observatory, telescopes of the reflecting type such as Herschel built were again to come to the front in astronomy. The reflector has many advantages over the lens or refracting type of telescope, particularly, when, as in modern astronomy, almost all of the work is done by photography. Furthermore, it is possible to obtain discs of glass for a reflecting surface far greater in size than could be obtained for the making of a lens through which light must be transmitted, a 200-inch lens would require an unattainable homogeneity from the glass manufacturers.

Probably the greatest contributions that have come from the large 60-inch and 100-inch telescopes that have been at work at Mount Wilson, and the other large instruments elsewhere, are those that have furthered our ideas both as to the evolution of the stars, their distances, distribution, motions, and the construction of the universe. From the time when the Harvard Observatory first completed its orderly classification of stellar spectra in the monumental Henry Draper Catalogue, it had been seen that an evolutionary sequence in the growth and decay of stars was apparent. Working on the observational data from the large observatories, Professor Russell of Princeton has been able to establish a sequence in the growth of stars from the dull red gaseous bodies to white-hot stars, then back again to dull red bodies. The bright red star Betelgeuse in the quadrilateral of Orion is a typical star near the beginning of such an evolutionary sequence. It is a giant star, a million times as big as our sun. Its reddish glow and its complex banded spectrum indicate a surface temperature of some 3,000° absolute. According to current evolutionary theory such a star is destined to contract under its own gravitation, increasing its density and rising in temperature. Characteristic of its light, it will change from red to yellow and ultimately to white. The white-hot stars attain temperatures of some 20,000° absolute. At such high temperatures the spectra of these stars, of which the bright star Vega is typical, are relatively simple. A continuous spectrum stretching from the red far into the blue is crossed chiefly by the lines of hydrogen and helium. In the hotter star, the mutilated atoms have ionized helium, betraying themselves in a conspicuous series. As these white-hot denser stars contract they radiate more energy than they create and the temperature slowly falls. With the fall in tempera-

ture, ionization of gases in the atmosphere of these stars decreases and the heavier elements reappear in the spectra in increasing numbers. Continually shrinking in size and cooling in temperature, the stars become dull red bodies again, but this time of dwarf-like proportions. As temperatures continue to decrease, radiation becomes insufficient to register their presence in the usual way.

Within the last year, plates extremely sensitive to infra-red light have been used by Hetzler at the Yerkes Observatory for discovering stars of such low temperatures as to be invisible by methods previously used. It seems not unreasonable that some of these emit scarcely any ordinary light at all. Their radiation is characteristic of that of a heated flat iron just beginning or perhaps just failing to glow.

A careful analysis of the spectra of stars, together with the development of the theory of ionization, made possible knowledge of the total light-emitting power and the temperatures of the surface of the stars of these several classes. Certain variations in the light of well-known stars in stellar clusters revealed a relationship between the absolute magnitude, or actual brightness of the stars themselves, and the period of fluctuation in the light of these so-called "variable stars." From an examination of many globular clusters of stars photographed at the Mount Wilson Observatory, Shapley was able to calculate the distances of these distant systems extending the supposed dimensions of the galactic system to a diameter of some 200,000 light years. The light year is the unit of distance and represents how far light will travel in a year. It is roughly six million million miles.

Hardly had the dimensions of our galaxy become fairly well established before the huge telescopes were exploring into the characteristics of the spiral nebulae which are distant systems far outside the galactic realm. With the 100-inch telescope at the Mount Wilson Observatory, Hubble was actually able to resolve the great Andromeda nebula into individual stars, and to find among them cluster-type variables whose periods revealed their luminosity, thus enabling him to calculate the distance to these exceedingly faint objects. The distance to the great nebula in Andromeda, the nearest of the extra-galactic nebulae, he determined as 900,000 light years. Thus while the size and general form of our own galactic system is taking shape, revealing itself very much like a lens-shaped or watch-like aggregation of suns, astronomy has already begun the exploration of universes beyond our own.

Meanwhile, from the shift of the lines in the spectra of the stars betraying their velocity, the rotation of our whole galactic system has become established; a rotation about a center that appears from our earth to lie not very far from the region of Sagittarius in the Milky Way. The sun takes its place somewhere near but not in the central plane of this watch-shaped galaxy and roughly half-way from the center towards the periphery. In common with many other stars it circulates about the

galactic center carrying its planetary system with it at such a speed as will complete a revolution in some 250,000,000 years. The accumulation of star positions and comparisons with the earlier records give reasonable confirmation for this circulating drift of the astral bodies.

When the shift of lines in the spectra of the extra-galactic nebulae came to be measured, it was found that with few exceptions these remote spirals all appeared to be receding from the earth at velocities increasing with their distance, aggregating speeds up to 20,000 kilometers per second. The idea that thousands of spiral nebulae should all be running away from us, as though they held some particular aversion to our own stellar system, seemed at first too ridiculous to merit any reasonable explanation. Meanwhile, however, the mathematical theory of relativity had been progressing and new theoretical models of the universe came to light almost overnight from the hands of the mathematicians. Einstein, De Sitter, Le Maitre, and Eddington have been outstanding exponents in this field of theoretical investigation. Considered upon dynamical grounds with the postulates of relativity as a working basis, it was found that a universe of stars might of itself be expanding or contracting in accordance with the nature of the assumption of a certain cosmical constant, "lambda," that enters the equations. Since the observational data from the telescope indicate the recession of the remote nebulae and a recession that apparently increases with distance, it was natural that the value of this mathematical constant should be so taken as to fit the observational picture. We have had, therefore, for some time as one of the most fascinating doctrines in the new universe of today, the theory of a continued expansion. In such a picture every stellar system and every spiral nebula would appear to be increasing its distance from every such similar object, no matter what the vantage point of our observations might be. As the printed letters of the festive toy balloon increase their size and distance from one another while the balloon is inflated, so indeed by this crude analogy we picture the stars and galaxies increasing their distances from each other with the inflation of the universe itself. Here is a doctrine of inflation involving other than economic worries!

Some scientists, however, have oftentimes sounded notes of caution in the acceptance of the theory of the expanding universe. We must remember that there are other solutions of the cosmic equation. The solution which favors the expanding universe theory has been adopted because it seemed to be the one which fitted best the interpretation of the shifting of the lines in the spectra of distant nebulae towards the red end of the spectrum. This we have previously explained is what will happen if an object is rapidly receding from the observer. On the other hand, if we were ever to entertain the idea that the frequency in the vibrations of the light waves from remote objects slows down after thousands of years of journeying through interstellar space, this lowered frequency would produce precisely the same effect in shifting the lines in the

spectrum towards the red, as would be the case if these remote objects were actually running away from us.

Within the last six months, Professor Haas of Vienna has astounded the scientific world with calculations in regard to the total amount of energy contained in the universe. The outcome of his calculations indicates that there is not enough energy within the universe to create any such expansion as has been postulated. He has shown mathematically that there is not enough energy in each gram of matter to have enabled the universe to have grown to double its original size. To double distances between nebulae scattered uniformly in space would require, according to Professor Haas, about 1,300,000,000 years. While this seems perhaps to many of us an inordinate amount of time,—time is one thing of which the universe offers plenty,—it is not so very long in a scale of cosmic evolution. From a careful investigation of radioactivity within the crust of the earth, the age of our own planet has been rather definitely established as at least 2,000,000,000 years. Since then the earth is here, and has been here for 2,000,000,000 years, it appears that there has not yet been time enough during the age of the universe for it to have doubled itself in size. According to Professor Haas, it has not had enough energy to have done this even if it had so desired.

With such a bomb-shell thrown into the expanding universe theory, perhaps some physicist will yet be able to venture an explanation whereby radiation, losing energy in passing through interstellar space, is accompanied by a reduction in the frequency of the electromagnetic waves bringing light from remote regions. A note of caution has already been sounded. At the moment we are in a dilemma. We have no theory for a change in the frequency of light with distance, and we find difficulties in accepting an interpretation of a changed frequency that demands recession of the nebulae. If recession is the answer, then observations indicate velocities of expansion that, if Professor Haas is right, are quite untenable.

Such, then, is the picture of the universe that the mind of man has created out of innumerable observations that have come down from the ancients to modern time. Yet it should be recalled that from the dawn of astronomy to the middle of the 18th century, practically the entire time of both observing and theoretical astronomers has been spent in the solution of our own planetary system and the earth's motions. Only a little more than the last century has been devoted to the astronomy of the stellar systems. Most of our knowledge of the galaxy and the extragalactic nebulae has come out of only the last two decades.

In closing the picture of the new universe it is perhaps well to come back from the remoter regions to the planet on which we live, and to try to make out of the picture such significance as the universe may have for those of us imprisoned for our lifetime on the planet Earth. While science has been pursuing with its increasing measuring-rod the interstellar spaces, science has, at the same time, brought to light much new

knowledge in regard to our immediate cosmic environment.

After all, probably the one star in the galaxy of galaxies that concerns mankind more than any other is the sun. In it we literally live, move, and have our being. The sun is the closest to us of all stars, so near in fact that we see it as a full orb rotating on its axis. Through the telescope we watch in detail changes in its outer atmosphere. Yet, even so, we know all too little about some of the mysterious problems that concern it. The sun has definite cycles in its behavior as evidenced by the growth and decay of sunspots in approximate intervals of eleven years' duration. Measurements of the heat and radiation of the sun at the Smithsonian Observatory during the last few decades have indicated that the sun itself is a variable; that it sometimes sends us more heat and sometimes less heat. Furthermore, the quality of the radiation in sunlight appears to vary. The ultraviolet light from the sun, such as penetrates through the earth's atmosphere and is so necessary for the health of mankind, undergoes periods of fluctuation which appear to follow the eleven-year solar sycle. The ultraviolet light of the sun striking the upper regions of the stratosphere so electrifies it as to produce a sort of ceiling that reflects the electromagnetic waves of radio. Observations over the last ten years indicate that this ceiling periodically rises and falls in accordance with the outbreak and disappearance of spots on the sun's surface. Since the performance of your radio set, particularly as regards distant reception, depends upon the reflection of radio waves sent skyward, changes in the quality of distant radio reception follow markedly changes in the sun's performance. One would venture to say that here is a new tool for the solar astronomer. Unlike light waves, radio waves penetrate the clouds so that suitable radio equipment may yet make it possible to discover what is happening on the sun even though the sun itself were obscured by clouds for a long period. Disturbances on the sun itself are accompanied by disturbances in the earth's atmosphere which give rise to displays of aurorae, most frequently seen at times of sunspot maximum. The very air which we breathe is electrified or ionized. Some would have us believe that these ions in the lower air affect us physiologically in some mysterious way. Whether or not ions in the lower air vary with the number of ions in the upper atmosphere produced by the ultraviolet light of the sun, we do not know. We are investigating. Furthermore, millions of ions are continually being created in our atmosphere through the incoming cosmic rays, that penetrating radiation, whose origin is still much of a mystery. Are these cosmic rays high-speed electrons shot earthward from the remoter regions of space? Or are they photons, light pulses of exceedingly penetrating wave-length, even shorter than that of X-rays? Calculations by Millikan and others appear to establish definitely that they cannot be of atmospheric origin but have energy indicative of that released from the transmutation of elements. Four hydrogen atoms have the building materials for one helium atom. If, somewhere in the re-

mote regions of stellar space, they should decide on the creation of one such helium atom, they might coalesce, build an atom of helium, and scatter enough left-over energy to account approximately for the energy in the more penetrating cosmic rays. Thus Millikan has suggested that cosmic rays are the "birth cries of atoms" being born in interstellar realms. On the other hand, Jeans suggests that if atoms should suddenly annihilate themselves, the energy which would be released by the disappearance of their mass would be about equal to that of some of the cosmic rays. And so in equally poetic and sadder language, Jeans would have us believe that cosmic rays are the "death cries of atoms" passing into oblivion.

In looking into the future of science and our knowledge of the universe in the coming decades, I would venture to predict that we will see advances along two frontiers leading in two very different directions: (1) extending our knowledge of the remoter regions through the creation and completion of the 200-inch telescope in California, and (2) extending knowledge of our immediate cosmic environment in space, tracing certain mysterious changes in the earth and its atmosphere and perhaps even in its biological realm to changing conditions outside the earth itself. It already appears that periodical changes in the sun are responsible for more far-reaching consequences in the affairs of the earth than we have perhaps been wont to suppose. The field of investigation into cosmic and terrestrial relationships is just beginning. For want of a better term that will tersely express the new field in science, I am suggesting the word "cosmecology," the study of the relation of the earth to its cosmic environment.

Massachusetts Institute of Technology, Cambridge, Mass.

AQUARIUS

Aquarius shall pour her stars forever,
Drops forever trickle down the night;
Each time the wood duck vaults the southern hill
To take the invisible tunnel of her flight,
Aquarius shall rise from out the dusk
And tilt her bowl of stars to light the way;
Aquarius shall empty stars forever
Though the last wood duck be lost in clay.

Frances Morton O'Neill.

Bittersweet Hill, Athens, Ohio.

Collecting Data on Meteors and Fireballs

By RAYMOND E. CRILLEY

During the past few years there has been much discussion as to the value of different methods of collecting data on spectacular meteors and fireballs. I have never considered any method equal to that of conducting personal interviews at the actual spot of the observation. There is much to be said for this method but I am by no means convinced that it is the only way of collecting reliable data. Information of much value may be collected by mail if an effort is made to help the observer to overcome probable errors in the making of his report.

Meteor paths must be computed from the data gathered from untrained observers, as they constitute the great mass of persons who witness the phenomena. I have spent a number of years in the study of these events and in this time have never had the good fortune to see a really spectacular fireball. The problem before us is to secure reliable and accurate information from persons with no special training in such work. While the data secured by any method are usually discordant and subject to many errors, I feel that a study of this subject will lead to a greater understanding of the probable extent and nature of such error. Just how much of this error we can eliminate remains questionable even with the careful collection of data by conducting personal interviews. There is the problem of dealing with the variation in general intelligence and training of different observers, but even here the personal factor is distressingly large. Many persons are so startled by the phenomenon that it is difficult to evaluate data obtained from them after they have had the opportunity to talk over the matter with other observers. In some cases they have been influenced by hastily prepared press articles.

Little or no value can be placed on angular estimates of altitude and azimuth, when given in degrees. Many persons will be in error from five to thirty degrees in giving such reports and some instances may be found where the error is even greater. The observer may be able to point out the exact spot in the sky where he witnessed the meteor, but his estimate of the direction and altitude of this spot is of little use to the astronomer. I know of no astronomer willing to trust his own estimate of such angles. It is customary to register the results of such observations by the use of a Transit or the Altitudometer. The angles can be reproduced with fair accuracy, but even in this case they must be measured in the laboratory.

I have conducted a series of experiments with untrained observers and find the results to be very useful in illustrating the nature of the errors which may be committed in estimating the angles in degrees.

The group was stationed so that its members observed the same sec-

tion of the sky. When a meteor appeared, each one made an independent record of the estimated angles of the altitude and azimuth, both at the beginning and the end of the path. The observers were then asked to draw these angles, following the instructions given later in this article, and a study was made of the results. The estimated angles showed an average error of more than ten degrees from the mean, while those measured from the drawings and tabulated in the same manner resulted in an average error of less than two degrees. These experiments were carried on with a group of college men from my classes in mathematics. They were not a selected group, but all had had some experience in dealing with angles, a fact which might lead one to think that their estimates should be slightly better than those from a group without this advantage.

Most observers of meteors are attracted to this phenomenon while going about the ordinary pursuits of life. Not all are in what might be classified as the ideal position for making an accurate observation. I have had many reports from persons traveling in automobiles, on trains and in some of the instances from passengers and pilots of airplanes. While such reports are of some value, it is nearly always difficult to establish directions from such positions. One may know the general direction of the highway or the railroad, but due to the various curves and the almost hopeless task of fixing the exact spot from which the observation was made it is often difficult to secure reliable information. The ideal observation seems to be that of the person standing or sitting in a familiar place with some landmark or obstruction to use as a basis for fixing the points of the beginning and ending of the path of the meteor. Considerable weight may be given to the observation where the meteor appeared very near to some known landmark or the point of bursting is marked by a familiar tree or building. The observer standing or walking in a field, with an unobstructed view of the sky, enjoys the ideal opportunity for the actual observation, but angles taken from such points cannot carry the weight of those obtained by the use of some fixed landmark.

When it is not possible to arrange for a personal interview the use of questionnaires will often be the means of securing many reliable data on the meteor. In compiling such a questionnaire there are many points to be covered and many problems to be considered. If the questions are thoughtfully prepared and cover the important points, the information secured by this method should not vary greatly from that obtained by means of a personal interview. It must be remembered that in any method of securing data one cannot hope to correct or influence whatever impression was made on the observer by the fall of the meteor, but must endeavor only to draw out this information in an exacting manner. The interviewer may make suggestions and answer questions, but they can only lead to a better method of obtaining and recording the real impressions of the observer.

We have been able, during the past few years, to secure data on a number of important meteors by the use of questionnaires and in most cases have added to this information other data obtained by personal interviews. In a few instances it has been impossible to arrange for the interviews and we have been forced to rely on such facts as could be obtained by mail.

The great meteor of March 24, 1933, (Harding County, New Mexico), furnished us with an opportunity to study the results of entirely independent computations based upon these two methods of securing information.

A radio report of this meteor reached us early in the afternoon of March 24, and within five days we had requests, for the names of observers, published in more than thirty of the larger newspapers of Colorado, New Mexico, Texas, Kansas, Oklahoma, and Arizona. In a very short time more than four hundred letters reached us giving many colorful and interesting reports of this meteor. These letters were followed up by questionnaires and a great mass of information was secured. Within a few weeks of the fall a sufficient amount of data was at hand to allow us to make a preliminary estimate of the path of this meteor through the atmosphere. This preliminary report was placed at the disposal of Dr. C. C. Wylie, of the State University of Iowa, and was included in a paper dated April 23, 1933, and published by Dr. Wylie (P. A., Vol. 41, p. 281, May, 1933). Our first estimate of the altitude of the end point was placed at ten to eleven miles, which was later found to be rather low. Most observers are inclined to extend their paths too far so that one cannot hope for any great degree of accuracy at the end point until reports are tabulated from many observers as near to this point as possible.

When this preliminary report was made the writer was not aware that it was to be published, but our more detailed study served only to add strength to the path given in this estimate. This more detailed study of data served to decrease the angle of fall (with the horizontal) and as a consequence increased the altitude of the bursting point. A number of reports received after the preliminary estimate was made extended the point of beginning more to the east and confirmed our rather flat or horizontal line of flight.

Mr. H. H. Nininger, of Denver, Colorado, published a very interesting and complete account of this meteor, with his computations for the path, in a paper completed in May, 1934 (P. A., Vol. 45, p. 291, June-July, 1934). Mr. Nininger covered the entire territory, traveling over parts of five states, and conducted more than one hundred personal interviews with the observers of this meteor. Mr. Nininger is an enterprising and ardent worker in this field and as a result of his study the path of the meteor was well defined. The fact that fragments of the meteor were recovered along his computed path served to prove that the path was corrct. The rather remarkable similarity of the results ob-

tained by the writer from the questionnaires and by Mr. Nininger from the personal interviews may be seen by comparing the two publications heretofore mentioned.

During the past few years our astronomical magazines have carried the published paths of meteors that were computed from angular estimates of the points of beginning and ending. The probable error of such reports is greater than the writer would care to deal with in handling a problem so delicate as that of computing the path of a meteor through the atmosphere. The estimated size of well-defined angles is subject to great error. It is unlikely that an untrained observer, standing at the vertex of the angle to be estimated, can give information that is to be regarded worthy of consideration.

In conducting personal interviews with the observers of meteors the astronomer asks each observer to point to the exact spot in the sky where the meteor was seen to appear and then to follow the path to the point of ending or where it was observed to burst. These angles are then measured with the greatest of care, for even the trained astronomer will not trust his own estimate of the size of such angles. If no means of measuring the angles are available, they are reproduced and marked so that they may be measured later.

While the personal interview offers a number of advantages over any other method of obtaining information, to admit that it is the only reliable means would spell defeat for many persons interested in meteors. The collection of information by this method means weeks and sometimes months spent in travel; and very few persons can find time and means to carry on such a program.

At the organization meeting of the Society for Research on Meteorites the writer was named chairman of a committee for the purpose of formulating a suitable questionnaire. Having used this method of obtaining information on spectacular meteors for some time, and having already worked out a questionnaire, we sent copies of the one then in use to members of the committee asking for suggestions and improvements. Much valuable information and assistance were obtained from Dr. F. R. Moulton, Dr. C. C. Wylie, Dr. F. C. Leonard, Dr. G. M. Butler, Dr. H. W. Nichols, and Dr. W. F. Foshag. We offer here the resulting list of questions, together with the instructions for drawing angles of altitude and azimuth.

Questions to be Answered

The object of this questionnaire is to assist us in our efforts to learn more of the nature of meteors and meteorites. Even if you can answer only a part of the questions your information will be of value. The record of angles made according to the instructions given below would be of great assistance to our study of the meteor but, if it is inconvenient to make them, the questions should be answered anyway.

Name. Address. Give your location as exactly as possible at the time you saw the meteor.

When did you see the meteor? Give date, day of week, and exact time. What were you doing when you saw the meteor? Standing, sitting, walking, riding, etc.

How bright was the meteor in comparison with the brightest stars that you know, the planets, or the moon? Did it light up the sky like a flash of lightning?

If you saw shadows cast at the time, how sharp were they as compared to shadows cast at the time of full moon? What was the color of the meteor? If the landscape was illuminated what color did the light appear to be?

Did the meteor explode? If so, were there few or many parts?

Did the meteor leave a luminous trail? If so, how long by the watch did this trail last? How far did this trail drift with respect to known stars? What direction did it drift?

Did the meteor leave a luminous cloud, or smoke cloud? If so, how long by the watch did this cloud last? How far did this cloud drift with respect to stars that you know? What direction did it drift? Describe the change in shape of this cloud.

Did you hear any sound that you thought was caused by the meteor? If so, how loud was the sound and how long did it last? Did this sound come at the same time you saw the meteor, or later? How long after? (If you made no estimate of the time have someone hold a watch while you repeat your actions from the time you saw the meteor until the time when you heard the sound. Give this time in minutes and seconds. Be as careful and as exact as possible.)

Give any other available information about the meteor.

Have any parts of the meteor been found? If so, how many? When? Where? How were they found? By whom were they found? Give name and address of person now having these parts. Are the parts that have been found stone or metal? What is their size? Weight? What is their appearance and color?

Give the names of other persons who saw the meteor fall so that we may write to them for additional information.

Kindly answer as many of these questions as possible and return the questionnaire to Professor Raymond E. Crilley, Iowa Wesleyan College, Mt. Pleasant, Iowa.

Instructions for Drawing Angles

Obtain two long rulers, or yard sticks, (any sticks with a straight edge and three or four feet long will do), some sheets of paper and a pencil. Lay one of the sticks on top of the other and drive a small nail or tack through one end of them so as to fasten the sticks together at one end. Or the two sticks can be merely held together at one end. Now go to the spot where you were when you saw the meteor and do the following:

First—Place the sticks on a level surface with one of them pointing exactly north and then rotate or move the other stick so that it will point in the direction in which you first saw the meteor. Both sticks should be as nearly level as you can get them, one pointing north and the other in the direction of your first sight of the meteor. Slide a sheet of paper under the sticks at the point where they are fastened together and with the pencil draw the angle formed by the two sticks. Write NORTH at the end of the proper line and place a figure 1 (one) in the angle you have drawn. If you do not know north accurately, lay one stick pointing in the direction of the sun. Mark this line "To Sun" and record the date and exact time (hour and minute).

Second—Draw the second angle in exactly the same manner as the first but have one stick pointing north, (or toward the sun) and the other in the direction in which you saw the meteor when it burst or disappeared. Mark the north line (or sun line) and place a figure 2 (two) in this angle.

Third—Hold one of the sticks exactly horizontal, or level, and pointed in the direction where you first saw the meteor. Now move the other stick until it points to the exact spot in the heavens where you saw the meteor appear. Draw this vertical angle and place a figure 3 (three) within it.

Fourth—Hold one of the sticks exactly horizontal, or level, and pointed in the direction in which you saw the meteor burst or disappear. Move the other

stick so that it points to the exact spot in the heavens where you saw the meteor burst or disappear. Draw this angle and place the figure 4 (four) within it.

FIFTH—Face the direction in which you saw the meteor. Hold one stick exactly horizontal, or level, and with the end where the sticks are fastened together directly in line with the point where the meteor burst or disappeared. Move the other stick until it covers the apparent path of the meteor as it fell. Draw the angle and place the figure 5 (five) within it. This is the angle the last part of the meteor's path seemed to make with the horizon.

Were you helped in fixing the point of beginning or ending of this meteor by any building, tree, or other such landmark? If so, describe the landmark and give details.

Send these five drawings to Professor Raymond E. Crilley, Iowa Wesleyan College, Mt. Pleasant, Iowa.

While the above form of questionnaire is now in use we are constantly seeking to make improvements that will add to the accuracy of the information secured. Each observer is instructed to obtain assistance in drawing the angles and all are urged to send the answers to the questions even if they do not draw the angles. We have found that only about fifty per cent of the observers will take the time to draw the angles but since they constitute the more careful and exacting group this only serves to add weight to their reports.

IOWA WESLEYAN COLLEGE, MOUNT PLEASANT, IOWA,
December 7, 1934.

Jupiter in 1936*

By WALTER H. HAAS

During the summer of 1936 the planet Jupiter was a brilliant object in the southern sky. Although it was a striking object to the lover of nature, it was the despair of the planetary observer in the northern hemisphere seeking to draw its detail. Its meridian altitude at my station was less than thirty degrees. I kept it under observation from March 22 to September 9, and was favored only once with seeing as good as three on a scale of 1 to 5 (5 being best).

It was, nevertheless, in 1936 that the author attempted his first serious study of Jupiter. Working at Mount Union College in Alliance, Ohio, with a 10-inch refractor, the author and his co-workers, Messrs. Weldy and Roth, made thirty-six drawings. The author supplemented his work with thirteen drawings (a total of forty-nine) made at New Waterford, Ohio, with a 6-inch reflector. The larger telescope was, naturally, superior to the smaller one; but valuable confirmatory work was done with the latter.

The subject of color changes on Jupiter is very interesting. At the suggestion of Mr. Martz, the author undertook a small program of color work; and 139 color observations (Haas 118, Weldy 18, Roth 3)

*Communicated by E. P. Martz, Jr., National Director, Planetary Section, American Amateur Astronomical Association, Oak Park, Illinois.

were made upon the belts and zones of the planet. In this work three pairs of colored sun-glasses (one greenish blue, one reddish brown, and one light-greenish) were used as the color filters. These glasses were worn in the usual manner while looking through the telescope. Results were obtained by making a table of six columns in which were indicated belt or zone observed, date, longitude of central meridian, clearness of sky, color filter or filters employed, and colors seen.

Even so, color work on Jupiter is exacting and difficult for two reasons: (1) There are no large areas that may be considered neutral gray. (2) The differences in the colors themselves are very slight. Results were not striking; but we shall consider them in some detail, since color work on Jupiter is new and interesting.

The polar caps were whitish gray, although the north one was once recorded as white. The polar regions were neutral gray to the author; but Weldy saw distinct and different colors in each polar region one night in July and also four weeks later. The colors were not the same; neither was the central meridian. The north north temperate belt was gray except for a region near 250°. This part was gray in May, tan in mid-June, and greenish gray by mid-August. Weldy failed to confirm the last observation. The north temperate belt was gray until mid-July. A coppery color of varying intensity now appeared and affected most of the belt for five or six weeks. A part of the affected section may have been greenish gray for a time in early August. The south south temperate belt was gray, except for a section around 260°. This section was three times recorded as reddish, once in mid-May, once in late May, and once in mid-July. That portion of the planet south of the south temperate belt was dull yellow or grayish yellow, being noticeably duller in tone than the rest of the ball, from March to May. On July 4 it was like the rest of the planet. A change from white to bright yellow was suspected in the north tropical zone.

The predominant tone of the south equatorial belt was bluish gray. The blue was not striking and may have varied. Much of the belt became reddish the second week in July and remained so for several weeks. A reddish blue was recorded as late as August 12. A greenish tint was suspected near 0° on July 12. Weldy saw a blue, probably the same thing, at this place a few days later. The belt was bluish again by mid-August if not earlier.

The north equatorial and the south temperate belt are of a similar coppery hue. Changes probably occur, but the author could learn little of these changes. A red or brown color filter is essential. The north equatorial belt varied from cherry red through brownish red, coppery red, and reddish brown to brown. Changes probably occur in days, not in weeks, and appear to be localized to small sections of the belt. These two statements are really only intelligent guesses on available data. The south temperate belt was very similar to the north equatorial one. Critical work upon it was begun in mid-July. It was found to be duller and

more coppery than the north equatorial belt. Weldy called the former belt brick red on August 12. A few days later this south temperate belt became dull tan developing into a dull tan-brown red. It was tannish red by September 7. An interesting but uncheckable observation on March 22 called this belt bluish. Color changes are probably less localized and less rapid than in the north equatorial belt. Condensations in both belts were darker, sometimes blacker, than the rest of the belts.

The author would like next to explain terms used for certain types of marks he saw:

Condensations are relatively dense portions of belts.

Condensation-pairs are two condensations, one on the north and one on the south edge of a belt. They are a type of detail peculiar to the author's eye (though Weldy saw them very definitely in his third and last drawing) and not seen by most other observers. Peek of the B.A.A. considered condensation-pairs a very unlikely type of mark because the unequal rotation periods of the different edges of a belt (this would be especially true of a wide belt, such as the north equatorial) would soon cause the component condensations to drift apart from each other. *In this article, condensation-pair means, not necessarily an objective mark looking exactly as defined, but a type of detail interpreted in the aforesaid manner.* This reservation must be borne in mind. A certain type of objective detail on Jupiter is interpreted differently by different eyes, and the condensation-pair is merely the author's interpretation.

Peninsulas are pointed projections from the edges of belts.

Condensation-peninsulas are self-explanatory.

Enlargements are non-pointed projections from the edges of belts.

Notches are self-explanatory marks on the edges of belts.

Streaks are self-explanatory. The term is restricted to zone detail.

Wisps are narrow projections of belts running into the zones.

Rifts are breaks in belts.

Streaklets are very thin and very short streaks. They are at the very limit of vision.

White spots are self-explanatory zone detail. The author's eye is not sensitive to this type of detail. Roth saw a number of white spots along the edges of prominent belts, but these were probably not the same as those the author saw.

Longitudes given here were taken from drawings and may be badly in error for many marks.

The belts will be discussed in the order of their conspicuousness, as follows: North equatorial, south temperate, south equatorial, north temperate, south south temperate, north north temperate, and south south south temperate.

North Equatorial Belt. Easily by far the most conspicuous and usually the widest of all belts, this belt was composed of condensation of

varying intensity, was perhaps transversed by some rifts, was notched in places, and apparently had bright spots and dark streaklets near its edges. The condensation-pairs were surprisingly permanent, even though we find much variation in their permanency. At one extreme is a pair scarcely going unaltered two weeks on end; at the other extreme is a pair not changing at all in five and a half months. The tendency, however, was for those marks to last from two to four months or, if once distorted, to regain their original appearance. The author is confident that many of the condensations present at the end of August could be traced to mid-May. Single condensations appeared to be shorter lived than pairs, whatever this may signify. Peninsulas and enlargements seen in this belt were very transient and usually were associated with condensations. Notches were also temporary and were very definitely associated with the formation or breaking up of condensation-pairs.

South Temperate Belt. Less conspicuous and thinner than the north equatorial belt, this belt had, as its typical mark, the condensation-peninsula, situated, without a single exception, on the north edge of the belt. These peninsulas lack the permanence of the condensations in the north equatorial belt. The longest-lived one lasted only eleven weeks, and even five weeks was a long life. The south temperate belt altered considerably between May and August. Single condensations were seen, but pairs were rare. Notches, rifts, and enlargements were almost unknown. It is probable that, in spite of the impermanency of the markings, this belt is less active than the north equatorial belt. Perhaps the condensation-pairs in the latter belt serve as centers, from which disturbances reach adjoining regions. The motion of marks in the south temperate belt was in general swifter than system II. A number of anomalous motions were detected.

South Equatorial Belt. Perhaps varying in both intensity and width, this belt ranked third all year in conspicuousness. Its typical mark during May and June was an enlargement on the south edge, invariably associated with a condensation-pair. Very few enlargements were seen after the end of June. High powers were employed if at all possible (enlargements are usually best seen with low powers), the seeing was poorer than before, and the author had subconsciously trained his eye to the condensation type of detail. The belt also contained condensation-pairs, condensations, peninsulas, and rifts in that frequency of occurrence. The marks were of little permanency, eight weeks being the longest life detected for any mark. There was nevertheless, a tendency for the return of the *status quo* (especially among the condensation-pairs); and August witnessed the revival of a number of May and June marks.

North Temperate Belt. This belt was much vaguer than the first three, faded out entirely in May, and was thin all during June. The

condensation-pair was the dominating mark. Condensations were almost the only other type of mark seen. Detail was remarkably permanent, and the belt was very inactive.

South South Temperate Belt. This belt was so vague that it was usually seen as several unconnected "condensations" (by analogy from prominent belts). The belt was like the north temperate belt in its detail and in its inactivity. There were three possible deviations in the motions of the marks from system II: One mark gained several degrees in ten days, another gained ten degrees in two weeks, and another lost ten degrees in six weeks.

North North Temperate Belt. Though ranking fourth among Jovian belts for a time in late May, this belt was usually so vague as scarcely to be distinct from the north polar shading. It was very inactive and lacked detail. Three changes were suspected including the temporary appearance of two peninsulas and the fading to vagueness of a condensation conspicuous a few days before.

South South South Temperate Belt. Though very vague indeed, this belt was comparable to the north north temperate belt and was unusually conspicuous in the latter half of June. Its marks were rather permanent, as nearly as could be ascertained of such difficult detail. A peninsula was seen on the north edge of the belt on June 26.

Equatorial Zone. This area was by far the most active of the zones. As many as a third of its marks were seen only once, and others lasted about a week. A few streaks endured from May to August. The most interesting marks were the white spots; strongly suggesting by their color our own summer-days, white cumulus clouds. The author saw thirteen such spots in this zone between July 13 and September 5. A few of them touched the north equatorial belt, the belt being much disturbed in their neighborhood. Two of them were seen a month after their first appearance and had lost five degrees of longitude (I).

South Tropical Zone. This, the widest of the low latitude zones, was similar to the equatorial zone. The typical mark was a streak lasting for a few weeks.

Great Red Spot. The Red Spot is probably the most interesting mark on Jupiter. Martz and Wilson agree that it was conspicuous, that it lay in the south tropical zone near the south temperate belt, that it was of oblong shape, and that it often seemed hollow because of the obscuration of its center by whitish material. The author saw the Red Spot seven times between April and September. It usually appeared as an area enclosed by two curving streaks (author's interpretation of "hollowness" seen by Martz and Wilson?). Its longitude, as estimated from the author's drawings, was 140° (II) before the end of June, 145° in early August, and 150° in late August. It was seen central on Jupiter at 1:25 G.C.T., on September 9. This would give a longitude of 151°

(II). Wilson, making careful measures of its longitude, placed it at 143° during most of the year and at 147° near the end of August. Wilson and the author both appear to agree that the mark was decelerated in August. But Peek of the B.A.A., who also made careful measures of its longitude, writes, "The Great Red Spot could not possibly have been at 150° in September." The possible deceleration remains controversial.

NORTH TROPICAL ZONE. The marks of this zone moved a little faster than II and were probably affected by the adjacent north equatorial belt.

SOUTH TEMPERATE ZONE. This zone contained a small amount of very vague detail and followed system II.

NORTH TEMPERATE ZONE. This zone contained a few very vague streaks, which appeared to move a little more rapidly than II. Marks were too few to detect abnormal motions with any certainty.

SOUTH SOUTH TEMPERATE ZONE. Its few vague streaks did not follow system II. Whether fast or slow could not be determined.

NORTH NORTH TEMPERATE ZONE. The amount of detail seen here was surprising, even though this detail was very difficult. The dull yellow of the zone was a poor background for vague streaks. One streak lasted fifteen weeks; another (probably) four and a half months; but still another faded considerably in a single day. A surprising number of white spots were seen in this zone, without exception on the limb. They were invisible when centrally placed, perhaps because of the background. A number of them were seen twice, some three times, and one four times. They are probably objective.

SOUTH POLAR REGION. The only mark was a thin band around the polar cap, this band being seen almost every time Jupiter was drawn. In it were seen a total of two condensations and five gaps, one gap attaining an age of three months.

NORTH POLAR REGION. This portion of the planet contained nothing but a small amount of uncheckable detail. An outstanding polar cap was seen twice. The cap-band, in which several long gaps were seen, was less distinct than the south polar cap-band.

An Addition to "The Forty Nearest Stars" in the March Issue

By ROY K. MARSHALL

Dr. Dirk Reuyl, of the McCormick Observatory of the University of Virginia, has called my attention to an omission in my list of the stars within 5 parsecs, which appeared in the preceding issue of POPULAR ASTRONOMY.

Stearns at Van Vleck Observatory published a value of 0″.250 for the parallax of Ross 614, after the publication of the 1935 Yale Catalogue. Reuyl investigated the star and found its motion to be irregular, because of the presence of a dark companion; he gave, as the value of the parallax as determined at McCormick, 0″.262.

The latest list of parallaxes determined at the Cape of Good Hope (published in *Monthly Notices*, **97**, 79, November, 1936) gives the following information concerning the star:

Ross 614; ptg. mag. 12.6; R.A. $6^h\,24^m.3$, Decl. $-2°\,44'$;
parallax 0″.262; proper motion 1″.018.

Using this value of the parallax and proper motion, the linear velocity with respect to the sun (the component perpendicular to the line of sight) is 18 km/sec; the absolute magnitude is +14.7, which makes the star tied with Innes' star for the fourth faintest star in the list. Since, according to Reuyl, the star has an invisible companion, there are 42 stars within 5 parsecs of the sun.

Another star, referred to in *Harvard Announcement Card* 405 under date of February 19, 1937, as a faint proper motion star, apparently also should be included. This star, discovered by Dr. Luyten at the University of Minnesota on plates taken with the Harvard 24-inch Bruce refractor, is designated as L 789-6; it is at $22^h.5$ right ascension and −15°.7 and has a photographic magnitude of 14.3. The proper motion is 3″.27. Measurement of six plates made with the 16-inch Metcalf refractor at Oak Ridge gives a preliminary value for the parallax equal to 0″.53. With this admittedly uncertain parallax, the cross motion with respect to the sun is 29 km/sec, and the absolute magnitude is +18 (ptg). This is considerably fainter than any star whose distance has previously been determined, to the best of my knowledge. The sun is 13 magnitudes, or about 150,000 times, brighter than this star,* if the tentative value of the parallax is near the truth.

If there are other additions to this list, I shall be glad to receive them.

*Assuming this new star and the sun to be of approximately the same color.

Planet Notes for May, 1937

By CLIFFORD E. SMITH

Note: All times, unless otherwise stated, are Central Standard Time.

The *Sun* will be moving with an apparent northeasterly motion from the central part of Aries to the central part of Taurus. Its distance from the earth will increase from about 93.6 to about 94.2-million miles. Its position on the first and last days of the month will be, respectively: R.A. $2^h\,31^m$, Decl. +14° 53′ and R.A. $4^h\,30^m$, Decl. +21° 49′.

The phenomena of the *Moon* will occur as follows:

Last Quarter	May	3 at	1 P.M.
New Moon		10 "	7 A.M.
First Quarter		17 "	1 A.M.
Full Moon		25 "	2 A.M.

Mercury will be near the border of Aries and Taurus. Until May 11 it will be an evening star, but rather near the sun in apparent position. On that date conjunction with the sun will occur. This will be a particularly interesting conjunction because Mercury will partially transit the sun* By the end of the month it will be a morning star rising about an hour and a half before the sun. The distance of Mercury from the earth will be about 60 million miles, and its apparent diameter will vary from a little greater to a little less than ten seconds of arc. The conjunction of Mercury with the moon this month will occur only a few hours before conjunction with the sun will occur. The position of Mercury on the first and last days of the month will be R.A. $3^h\ 26^m$, Decl. $+21°\ 04'$ and R.A. $3^h\ 02^m$, Decl. $+13°\ 16'$.

Venus will be a morning object in Southern Pisces, and it will rise about three hours before the sun. Its distance from the earth will increase from about 30 to about 45 million miles. The corresponding change in apparent diameter will be from about 54 to about 34 seconds of arc. Greatest brilliancy for this elongation will occur on May 23 at 7:00 P.M. Conjunction with the moon will occur on May 8 at 9:00 A.M. (Venus 2°.6 S).

Mars will be a night object in northern Scorpio. It will be above the horizon most of the night hours since opposition with respect to the sun will occur on May 19 at 1:00 P.M. Its distance from the earth will be about 50 million miles, and its apparent diameter will vary from about 16 to about 18 seconds of arc. Conjunction with the moon will occur on May 24 at noon (Mars $0°\ 33'$ S).

Jupiter will be a morning object near the western boundary of Capricornus. During the middle of the month it will rise about 11:00 P.M. local time. Its distance from the earth will be about 430 million miles, and its apparent diameter will be about 40 seconds of arc. Conjunction with the moon will occur on May 2 at 8:00 A.M. and May 29 at 2:00 P.M. (Jupiter 3°.8 S).

Saturn will be a morning object in southern Pisces, and, during the middle of the month, it will rise about three hours before the sun. Its distance from the earth will be about 940 million miles and its apparent diameter will be about 15 seconds of arc. Conjunction with the moon will occur on May 7 at 7:00 A.M. (Saturn 7°.7 S).

Uranus will be too near the sun in apparent position to be of general interest since conjunction with respect to the sun will have occurred on April 30.

Neptune will continue as an evening object in southern Leo. During the middle of the month it will be toward the south (on the meridian) about 8:00 P.M. local time. Its distance from the earth will be about 2800 million miles, and its apparent diameter will be about 2½ seconds of arc. Conjunction with the moon will occur on May 18 at 8:00 P.M. (Neptune 6°.9 N). The position of Neptune on May 15 will be R.A. $11^h\ 11^m$, Decl. $+6°\ 26'$.

Asteroid Notes

Asteroid Notes will appear again in the following issue.

*For diagram and further details see page 31 of the January (1937) issue of POPULAR ASTRONOMY.

OCCULTATION PREDICTIONS

(Taken from the *American Ephemeris*)

Date 1937	Star	Mag.	Immersion: Greenwich C.T.	Immersion: *a*	Immersion: *b*	Immersion: Angle E from N	Emersion: Greenwich C.T.	Emersion: *a*	Emersion: *b*	Emersion: Angle E from N
			h m	m	m	°	h m	m	m	°
Occultations Visible in Longitude +72° 30′, Latitude +42° 30′.										
May 1	33 Sgr	5.8	4 43.6	−0.7	+1.5	89	5 58.0	−1.3	+1.3	263
1	ξ Sgr	3.6	7 8.9	−1.9	+1.8	50	8 27.1	−2.2	−0.1	288
3	τ Cap	5.3	7 12.6	−1.2	+2.1	51	8 26.0	−1.6	+1.0	272
25	δ Sco	2.5	1 59.0	−1.3	+0.7	108	3 22.8	−1.8	+0.3	282
30	31 B.Cap	6.4	9 38.1	−2.3	−0.8	100	10 42.9	−0.6	+1.2	205
Occultations Visible in Longitude +91° 0′, Latitude +40° 0′.										
May 1	ξ Sgr	3.6	6 34.8	−1.3	+2.0	64	7 49.9	−1.5	+0.7	284
3	τ Cap	5.3	6 51.7	−0.6	+2.0	61	7 58.3	−0.9	+1.3	269
25	δ Sco	2.5	1 45.6	−0.1	−0.2	140	2 47.1	−1.6	+1.7	253
30	31 B.Cap	6.4	8 55.3	−2.2	+0.8	80	10 19.8	−1.6	+0.9	229
Occultations Visible in Longitude +120° 0′, Latitude +36° 0′.										
May 15	2 B.Cnc	6.2	4 45.9	−0.8	−0.8	80	5 36.2	+0.2	−2.2	325
21	370 B.Vir	6.0	7 20.5	−1.5	−2.1	136	8 35.7	−1.3	−1.4	272
21	BD—11°3398	6.5	9 48.3	..	..	182	10 7.1	..	..	215
27	21 G.Sgr	5.7	12 32.6	−1.4	−0.9	87	13 45.9	−0.5	−0.4	243
30	31 B.Cap	6.4	8 2.0	−1.2	+1.6	78	9 20.6	−1.6	+1.5	248

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result, in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

In Meteor Notes it is my purpose, at intervals, to publish work by others, dealing with the subject. Therefore, this time, besides the part written by myself appear the results on the fireball of 1930 May 3 by Dr. S. G. Barton of Flower Observatory, and also a complete and interesting paper by Professor C. Hoffmeister of Germany, which he desired me to have published. I may remark that a copy of a book by this eminent authority, "Die Meteore," has just been received from Leipzig, which I am now reading and later hope to review at length. I do not hesitate, however, to recommend at once that all our members who can read German purchase this book. It is mainly concerned with the most modern aspects of meteoric astronomy. Almost simultaneously has arrived another publication by E. Öpik dealing with the Arizona meteor expedition of a few years ago. This is *Harvard Reprint* No. 127, and in it are briefly discussed the heights of meteors

observed there and conclusions to be derived therefrom. This also should be generaly read, but again no review will here be attempted as Öpik promises a larger paper with full details. Until this appears it is difficult to discuss intelligently certain statements he makes, particularly the one in which he claims that meteor heights, derived from A.M.S. data, are systematically too high. Yet our Leonid heights are far lower than the older ones of H. A. Newton and a very little lower, though in excellent agreement, with those published recently in Russia by Fedinsky. However, to go further into the discussion now would be fruitless.

Of the three fireballs here given, as said, the first is by S. G. Barton, the other two by me, assisted on the third by Mrs. D. M. Wills. Hoffmeister's article forms the last part of these Notes.

Fireball of 1930 May 3

A brilliant fireball which appeared on 1930 May 3 at 8:55 E.S.T., over Virginia, was observed and reported by 19 persons scattered from Kingston, North Carolina, to Holicong, Pennsylvania, and as far west as Blacksburg, Virginia. The list of observers is omitted to save space, but our sincere thanks are due to them all. The fireball was observed to be from one quarter to three quarters as large (bright) as the Moon. A short train of brief duration was noticed. The fireball was usually described as white or yellow and the train as red. Most observers reported that it exploded. Contrary to usual experience the beginning point was probably better determined than the end point. The time of flight based on estimates ranging from 1 to 10 seconds was taken as 4.5 seconds. This would imply a hyperbolic velocity with respect to the Sun of 61.5 km/sec, but due to the inevitable errors of observation and to the fact that the end point was not fixed with great accuracy, it seemed better to compute the orbit on the usual assumption of parabolic velocity. The following data were derived:

Local sidereal time at end point	171° 32′
Began over	$\lambda = 80°\ 12'$ W, $\phi = +37°\ 10'$
Ended over	$\lambda = 78°\ 55'$ W, $\phi = +36°\ 51'$
Height at beginning	141 km
Height at end	37 km
Projected length of path	104 km
Actual length of path	146 km
Radiant	$a = 120°\ 27'$, $h = 45°\ 0'$
Zenith correction	5° 50′
Corrected radiant	$a = 120°\ 27'$, $\alpha = 103°\ 15'$, $\lambda = 100°\ 12'$
	$h = 39°\ 10'$, $\delta = +43°\ 48'$, $\beta = +20°\ 49'$

From these data the following orbit was computed:

Epoch	1930 May 4.080
Perihelion distance	0.9745
Longitude of node	42° 53′
Longitude of perihelion	201° 41′
Inclination	7° 09′

This fireball was wholly worked up by my colleague, Dr. S. G. Barton.

Fireball of 1934 March 31

A splendid fireball was observed due east of the coast of Massachusetts at 6:24 G.M.T. on 1934 March 31. Two observations from ships came in to the headquarters of the American Meteor Society and formed the basis of this solution. These ships were:

1. Belgian steamer *Henri Jasper*, in latitude 41° 21′ N., longitude 64° 25′ W.
2. British steamer *Bradesk*, in latitude 42° 15′ N., longitude 66° 16′ W.

By the graphical method of solution for heights, in which the aimuths are taken as correct and the mean of the altitudes as being true, the following data were found:

Sidereal time at ground point	217°
Began over	$\lambda = 67° 44'$, $\phi = 41° 21'$
Ended over	$\lambda = 66° 28'$, $\phi = 41° 55'$
Height at beginning	68.5 ± 13.8 km
Height at end	20.8 ± 0.9 km
Projected length of path	122 km
Actual length of path	129 km
Observed velocity	18.5 km/sec
Radiant (uncorrected)	$a = 59°$, $h = 21° \pm 5°$
Zenith correction	7°7
Radiant corrected,	$a = 59°$, $h = 13°3$, $\alpha = 157°3$, $\delta = -12°4$

No definite estimate of the magnitude of the fireball was attempted, but obviously it was extremely brilliant. It began as green, but there is some contradiction about its final color. It left no long-enduring train. The low altitude at which it disappeared makes it probable that fragments dropped into the ocean.

Fireball of 1933 July 23

At 5:40 G.M.T. on 1933 July 23, a brilliant fireball fell over the western Atlantic Ocean, bursting at a considerable height above the water. The following four accounts by ships' officers (positions in order from north to south, S1, S2, S3, and S4) were published in the *Hydrographic Bulletin*, U. S. Navy. The second paragraph under S1 summaries additional information obtained from that observer by letter.

S1. "Second Officer F. Sundlof, of the American steamer *I. C. White*, Capt. W. S. Evans, reports that on July 23, 1933, at 0540 G.M.T., in lat. 33° 38′ N., long. 76° 13′ W., a meteor was observed for about 3 seconds. The body appeared midway on a line drawn between Saturn and σ Sagittarii and traveled toward α Pavonis. The meteor was orange in color, changing to yellow and finally to a brilliant green of such intensity as to sharply define the southern horizon and to illuminate a cloud bank on the horizon when it disappeared behind it. The weather was clear . . ."

The path was vertical or nearly so, terminating a little to the eastward of the south point of the horizon. The approximate altitude of the cloud bank was 15°. The star α Pavonis itself was not seen, but the plotted path led in its direction. The brilliancy of the meteor increased rapidly throughout its path.

S2. "Third Officer E. B. Quigley, of the American steamer *Francis E. Powell*, Capt. M. E. Dahl, reports that on July 23, 1933, at 0540 G.M.T., in lat. 33° 13′ N., long. 76° 42′ W., a blue-white meteor about four times the size of Sirius was observed. The body fell perpendicularly from below γ Gruis at an altitude of 16°, *nearly to the horizon*, leaving a long white trail which was visible for several seconds. The meteor passed through clouds, upon emerging from which the color was dull red, but turned blue again, and was of such brilliancy as to make all objects visible. The weather was clear . . ."

S3. "Second Officer A. R. Truett, of the American steamer *John Worthington*, Capt. H. E. Clothier, reports that on July 23, 1933, at 0540 G.M.T., in lat. 31° 03′ N., long. 76° 44′ W., a brilliant meteor, about five times the size of Sirius, and resembling a reddish-white ball, was observed falling vertically from an altitude of about 30°, bearing 135°. The meteor fell slowly leaving a bluish-white trail the entire length of its course, burst about 5° above the horizon, giving off red, white, and blue colors which illuminated the whole sky brilliantly. The phenomenon was visible about 15 seconds."

S4. "Third Officer H. J. Weichard, of the American steamer *Golden Hind*, Capt. P. R. Jones, reports that on July 23, 1933, at 0539 G.M.T., in

lat. 27° 32′ N., long. 74° 14′ W., a large brilliant meteor was observed falling vertically near the constellation Cygnus from an alttude of 55°, bearing 330°. It changed color through the primary colors of the spectrum while falling and burst at an altitude of about 30°, leaving particles which fell to the horizon. The phenomenon was visible about 20 seconds. Weather partly cloudy. . ."

As it happened, these four vessels were all not far from one great circle. Efforts were therefore made to obtain an observation made at right angles to this circle, but without success. The solution, therefore, depends upon these four only.

The path being reported vertical from four different points, it would appear that a solution would be easy. But when we try to satisfy the altitude angles for beginning and end points, difficulties are at once met. Remembering that 3 of the 4 ships report clouds and that no four observers ever see an object for the first time at the same absolute moment, we may fix the beginning point in either of two ways: (a) by altitudes from S1 and S4, assuming those from S2 and S3 are points farther down the path; (b) by altitudes from S2, S3, and S4, omitting that from S1 as erroneous. As it happens, both solutions give almost the same slope; only the height of beginning point and the length of path are different. The second solution is probably the more nearly correct.

For the end point, the altitude from S1 is ruled out, as the meteor disappeared behind a cloud bank. The altitudes from S2, S3, and S4 agree splendidly.

No solution can be made for the plane of motion if the azimuths from S1 are used as printed in the *Hydrographic Bulletin*. If, however, the observer's subsequent statement in a letter, "a little to eastward," be assumed as 10° E of S, the azimuth fits in well when the plane is taken as passing through S4, the nearest ship, and bisecting the distance S2 to S3. This treatment of the data seems to give the most nearly correct solution.

The following results were finally derived:

Began over	$\lambda = 74° 50'$,	$\phi = +28° 40'$
Ended over	$\lambda = 74° 31'$,	$\phi = +28° 06'$
Ground point	$\lambda = 74° 27'$,	$\phi = +27° 57'$
Local sidereal time at ground point		311°.2
	(a)	(b)
Beginning height	(335)	169.3 km
Bursting point		36.8 km
Length of path	(339)	147.2 km
Slope of path		63°
Azimuth of motion (from)		155°.5
Radiant (uncorrected)	$a = 155°.5$	*h = 63°
	$\alpha = 293°.5$	$\delta = +51°.2$

According to S4, which was most favorably placed, particles fell to the horizon. From this and other evidence meteorites may be inferred. Apparently the fireball changed color during flight, but ended as white-green-blue or some combination thereof—opposite of red. No long-enduring train is mentioned. If we take the average of estimates of time from S3 and S4 (15 and 20 seconds respectively), the duration of the "phenomenon" was 17.5 seconds, but it is doubtful if this means time of flight only. If it does, the average geocentric velocity is only 8.4 km/sec. This is unexpectedly if not impossibly low for the highly inclined path, and makes one suspect that the time estimates are too great. In fact, such a low velocity could only be possible as a consequence of very great atmos-

*The correction for zenith attraction, assuming parabolic velocity, would be only 1°.6, hence the corrected h would be 61°.4. Due to uncertainties in data, to apply this seemed an unnecessary refinement.

pheric retardation. There is no reason to believe this was the case. The body when first seen was only four or five times the brightness of Sirius (or about equal to Venus), but when it burst it was evidently extremely brilliant indeed. No quantitative estimate is available.

A word of warning should now be given: observers on ships should be sure that the latitude and longitude are given accurately *for the time at which the meteor appeared*. Otherwise, no matter how accurate the observation, when it is combined with observations from other ships the results are bound to be erroneous. For this object, three out of four observations are satisfied almost exactly, and the results are probably considerably more accurate than is usual for fireballs.

This solution is another example of the happy results of the coöperation of ships' officers in gathering meteor data. Their assistance is most gratefully acknowledged.

Flower Observatory, 1937 March 16.

New Cosmic Relationships of Meteors

By C. HOFFMEISTER*

The increased attention now being paid in many countries to the study of meteors is due, no doubt, to the intermediate position which they occupy between Astronomy and Geophysics. On the side of Geophysics attention may be drawn, for example, to the connection between Meteoric Astronomy and the exploration of the propagation of Radio Waves (see "Forschungen und Fortschritte," **10**, 332, 1934). The present paper, on the other hand, deals with an extension of our knowledge towards the astronomical side.

The writer had obtained strongest evidence in 1922, that the majority of small cosmic bodies which, when penetrating into the Earth's atmosphere, cause the phenomena of shooting stars, are of interstellar origin; that is to say, that they do not originate in the Solar System, as cometary meteors do, but move through it from interstellar space in hyperbolic orbits. The present paper describes the further development of this investigation.

The reader will recall, that the Sun with its planets is moving towards a point in the constellation Hercules, near the boundary of Lyra, with a velocity of about 19 km/sec. The problem, in what way this fact influences the number and distribution of interstellar meteors observable at the Earth's surface, had been treated theoretically by G. v. Niessl long before there was any positive indication of an observed effect of this kind. The first observational indication of such an effect, found by the writer in 1922 in addition to the discovery of interstellar origin, remained entirely provisional at that time and was even temporarily rejected later on in favor of another hypothesis. But the results of observations obtained on an exploring voyage to the tropical Atlantic Ocean in 1930 pointed anew to an effect of peculiar motion of the interstellar meteor system and a further investigation of this subject was made possible by a second expedition in 1933, by Dr. N. Richter of Neubabelsberg and the writer, extending to 35° of southern latitude.

It will be easily understood that the frequency distribution of interstellar meteors over the different zones of the Earth depends on the original distribution of the directions from which the meteors penetrate into the sphere of attraction of the Sun, although the Sun's field of gravity to some extent modifies the real

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distribution and flattens the extreme value. If, for example, there is *one* preferential direction of motion in interstellar space, the effect as observed from the Earth will be that somewhere in the sky there will occur a concentration in the density of the radiation points. It must be remembered, however, that a terrestrial observer sees only the meteors coming from *one* hemisphere, namely that above his horizon, and the effect of any departure from uniform distribution of the points of radiation, therefore, is superposed on the effects of the Earth's rotation and revolution. Broadly speaking, there is an annual variation in the number of meteors visible from a given point on the Earth, due to its revolution around the Sun, on which are superposed the variations which are due to the Earth's rotation on its axis, arising from the varying position of the observer throughout the 24 hours in relation to the advancing hemisphere of the Earth as it moves in its orbit. After being freed from these influences, there will be a sine-shaped curve in the annual variation of frequency, the maximum frequency being observed when the region of greatest density of cosmic radiant points reaches its greatest altitude above the horizon at midnight.

It has been known since the time of Schiaparelli that the relation between meteor frequency observed on the back and the front hemispheres of the Earth, enables us to compute the real mean ("heliocentric") velocity of the meteors in their orbits. But this method is only correct when the distribution of the original directions of motion is uniform over the whole sphere. As this supposition is not in fact fulfilled there is an annual variation in the apparent mean velocity, the curve of which is also sine-shaped as a first approximation. This does not, however, detract from the value of the method, as the deviation between classical theory and observation can be used to investigate to what extent the real distribution of initial directions differs from uniform.

The observations from equatorial and southern latitudes, mentioned above, yielded an effect which was at first sight surprising; namely, the apparent heliocentric velocity in the months of northern spring was detected to be greater the more the observers moved towards the south. But it was found that this effect also could be clearly explained by the supposition of unequal distribution in the original directions, although in a somewhat complicated manner which cannot be described here in detail. But the existence of this effect may be regarded as an independent proof that this supposition is correct.

In addition to the observations mentioned above, 3 earlier series by northern observers and one by a southern observer extending over the whole year were included in the discussion. All 4 series showed the sine-shaped curve of cosmic variation of frequency, the southern curve showing parallel and not opposite variation to the northern ones. For velocity only one of the northern curves could be used. It showed the sine-curve of velocity clearly and also gave evidence of a difference of phases between the velocity and frequency curves of nearly the amount required by theory. From the extreme values of these curves it was possible to obtain a first approximation for the situation on the celestial sphere of the points of maximum and minimum density of the initial meteor directions.

These observations, in the writer's opinion, clearly establish the conclusion that there exists, in addition to the system of the stars, a system of minor bodies extending over interstellar space and that there is, at the present position in space of the Solar System, a current or drift in the interstellar matter directed from a point at about 50° of Right Ascension and 20° of northern Declination in the constellation of Taurus towards the opposite point near the boundary of the constellations Libra and Scorpius.

About 40 years ago G. v. Niessl discovered the existence of two non-cometary currents of meteors, one radiating from Taurus in October and November and the other one from Scorpius in the summer months, and later O. Knopf was able to extend the identification of these currents over the greater part of the year. There can be little doubt that there is some relation between these currents and the general drift of the Interstellar System, at least in the case of Taurus current moving with the system, although in the case of the Scorpius current moving in the opposite direction, the deviations are larger. We can hardly believe that these coincidences are accidental.

Attention may be drawn to the fact that v. Niessl found the velocity of the Taurus current to be greater than that of the Scorpius current. When freed from the influence of the Solar Motion the difference between the velocities of both currents may be regarded as twice the translational velocity of the interstellar system of meteors being about 10 km/sec. But this value must be regarded as provisional.

As to the structure and dynamics of the interstellar meteor system only a general outline can at present be given. There are two limiting possibilities; namely, motion of some only of the interstellar meteors in parallel paths and translation of the system, in so far as it is accessible to our exploration, as a whole. The truth probably lies between these limits, for on the one hand the existence of interstellar meteor currents is directly proved whilst on the other the interstellar system cannot be regarded as being at rest with reference to the Solar System; this would be a special case, the probability of which is very small. The interstellar system of minor bodies therefore seems to reveal a remarkable similarity to the Local System of stars.

There is another relationship which is nearly established. The direction of motion of interstellar meteoric matter connects two regions of the sky which are obscured by extended clouds of cosmic dust so that most of the stars seem to be considerably fainter than the stars of the same distance and absolute luminosity in adjacent non-obscured regions. Furthermore, star counts have shown that the distances of those clouds from the Solar System are exceptionally small both for the Taurus and the Ophiuchus-Scorpius regions. The German astronomers H. Müller and W. Becker have even considered the possibility of these two regions of obscuring clouds being joined, thus involving the Solar System in their midst. The writer's suspicion, already published in 1931, that interstellar meteors might be nothing else than the particles of interstellar clouds is thus gaining in probability, especially as recent investigations on the changes in the color of star light by interstellar absorption, by Schoenberg and others, have clearly shown that the obscuring clouds must contain particles of considerable size in addition to those extremely small particles responsible for producing color changes.

On Von Niessl's Velocities for Meteors

(Second Paper)

By C. C. WYLIE

In an earlier paper we summarized some of the results obtained for recent fireballs in Iowa and the adjoining states. Among the most important results are:

1. People who are out doors and away from lights in the territory lighted up by the meteor look up almost simultaneously when a bright meteor appears. The height at which different spectacular meteors first light up the landscape enough to

attract attention is nearly the same. The estimates of duration practically always refer to the interval from noticeable illumination to bursting.

2. There is a conspicuous psychological tendency to lengthen the path of a meteor, when it is not seen in good landmarks and familiar surroundings, or when an observer merely estimates the path, instead of pointing it out while standing exactly where he was when the meteor was seen.

When a number of different lengths of path are reported for the same meteor, a check shows that the shortest paths usually represent best the portion from noticeable illumination to bursting. It has been found that increased restrictions in the selection of fundamental data nearly always result in shortening the resulting path through the atmosphere.

3. The deceleration in velocity is too little to be detected from interviews with observers. As half of the air mass is always encountered in the last 3½ miles of height, we would expect a noticeable deceleration only near the end, if at all.

There may be an apparent deceleration when the motion of the meteor is nearly away from the observer, or an apparent acceleration when the motion of the meteor is nearly toward the observer. There may be a fictitious deceleration when the meteor falls from comparatively open sky to a region of good landmarks. The first part of the path, being poorly fixed is fictitiously extended. The velocity pictured for this portion of the path is too high. For the latter part of the path, fixed by landmarks, the mental image of distance travelled and velocity is more nearly correct.

4. For the great majority of well-observed meteors, elliptical velocities a little below the parabolic have been obtained.

5. It has been found that when the most discordant estimates of duration are discarded, the mean of a number of estimates should give a result reasonably near the truth. The error in duration should usually be less than the error in length of path.

Reproduction of action, or counting, gives the duration with much less uncertainty than a mere estimate.

Some Von Niessl Meteors

Let us now assume that we are dealing with meteors which are in reality about the same as those observed in Iowa and the adjoining states, and that the observations are subject to the same psychological errors. Let us examine the published results of Von Niessl to see whether there is evidence of fictitious lengthening. For the present, we will not consider the errors in duration since it appears they are of less importance than errors in length of path.

If one observer saw in reality several times the length of path seen by another observer, his estimate of duration should be much longer. If, on the other hand, all observers saw in reality practically the same length of path for the meteor, the average of the estimates of duration should be about the same for the short paths as for those fictitiously lengthened.

The following are some meteors for which Von Niessl has reported estimated paths of greatly different lengths:

Meteor	Long Path	Short Path
Sept. 23, 1910	231 mi. 5 sec.	50 mi. 5 sec.
Mar. 14, 1905	90 mi. 4 sec.	32 mi. 3½ sec.
Jan. 12, 1879	87½ mi. 3½ sec.	25 mi. 3 sec.

The fact that the estimated durations for the short and the long paths are practically the same indicates that the observed apparent paths were practically the same. This in turn indicates that the differences in the reported lengths are due to a fictitious extension. As was stated in the earlier paper, no other sensible interpretation appears possible. Von Niessl's results on these meteors have been widely quoted as evidence for a deceleration in the atmosphere; but what they really indicate is fictitious lengthening of path.

The Von Niessl-Hoffmeister Catalogue

1. If the highly hyperbolic velocities obtained for many of the meteors in this catalogue are real, we would expect the workers with the most experience to obtain as many such as the other workers. If, on the other hand, these high velocities are fictitious, we would expect the workers with the most experience to publish velocities averaging definitely lower than the other workers. A possible exception would be the experienced worker who is trying to demonstrate the reality of the highly hyperbolic velocities. He might, because of prejudice, keep the longer paths without sufficient investigation.

As a check on this point we have examined the Von Niessl-Hoffmeister Catalogue of 611 great meteors. The paths for which heliocentric velocities have been computed were combined in six groups according to distance from the apex. Denning was selected as an experienced worker who had computed the paths for a great number of the meteors. The six groups were formed separately for Denning and for all other observers with the following results in miles per second:

	0°- 30°	31°- 60°	61°- 90°	91°- 120°	121°- 150°	151°- 180°
Denning	24.4	23.5	27.5	28.7	30.8	30.7
Others	40.0	30.0	33.6	35.8	36.0	35.3
Difference	15.6	6.5	6.1	7.1	5.2	4.6

The fact that Denning's velocities average definitely lower suggests that restricting the data lowers the velocity. Probably a study of Denning's work would show that eliminating the results based on weaker data would reduce his velocities still further. This evidence is against the reality of the highly hyperbolic velocities.

2. The two viewpoints on the heliocentric velocities are: first, that the geocentric and heliocentric velocities in the catalogue are approximately correct, and that there is in reality the variation in heliocentric velocities which the catalogue indicates; or second, that the heliocentric velocities are in reality approximately constant, let us say nearly all between 18 and 25 miles per second, and that the extreme variation recorded is chiefly due to a fictitious lengthening of the path.

To get a point of distinction, note that nearly all meteors were observed before midnight. Only 38 of the 611 were observed between midnight and noon. This means that nearly all meteors were observed with the apex below the horizon and the anti-apex above. Meteors from near the apex must have had relatively flat and long paths. Meteors from near the anti-apex had steeper and shorter paths. For the same geocentric velocity, meteors from near the apex had lower heliocentric velocities, and those from near the anti-apex higher heliocentric velocities. Hence, for a given real geocentric velocity, the higher the heliocentric velocity, the shorter the path through the atmosphere.

Let us now consider the second viewpoint, that the heliocentric velocities were in reality nearly constant, and that the high velocities were due to fictitious length-

ening of the path. For a given tabulated geocentric velocity, the greater the fictitious extension was, the greater is the resulting figure for heliocentric velocity. The high fictitious heliocentric velocities actually correspond to the lower real geocentric velocities, and hence to the shorter real paths. But the fictitious extension would make the higher heliocentric velocities correspond to longer paths.

Here then, we have a simple and positive test for the high heliocentric velocities. If the geocentric and heliocentric velocities in the catalogue are real, a tabulation of the heliocentric velocities and lengths of path for the same geocentric values should show shorter paths through the atmosphere for higher heliocentric velocities. If in reality, the heliocentric velocities for the different meteors were about the same, and the difference is due to a fictitious extension of path, a tabulation of heliocentric velocities and lengths of path for the same geocentric values would show increasing length of path with increasing velocities.

To make this test, the meteors in the Von Niessl-Hoffmeister Catalogue, for which path length, geocentric and heliocentric velocities are given, were assembled in three groups according to geocentric velocity in miles per second. Each of these groups was in turn reassembled in three groups according to heliocentric velocity in miles per second.

To make the results somewhat smoother, the most extreme path lengths were deleted. The six longest paths out of the 123 paths in the group of geocentric velocity 6-18 miles were deleted; seven out of 177 in the group of geocentric velocity 19-30 miles were deleted; and three out of 83 in the group of geocentric velocity 31-43 miles were deleted. There were 35 meteors with a geocentric velocity of more than 43 miles per second. These were not included in the table. The inclusion of the extreme path lengths would not have affected the results, except that the table would not have been quite so smooth.

TABLE I

RELATION BETWEEN HELIOCENTRIC VELOCITY AND PATH LENGTH FOR METEORS OF THE SAME GEOCENTRIC VELOCITY OR BETWEEN GEOCENTRIC VELOCITY AND PATH LENGTH FOR METEORS OF THE SAME HELIOCENTRIC VELOCITY

Heliocentric Velocity Mi/sec	Geocentric Velocity 6-18		Geocentric Velocity 19-30		Geocentric Velocity 31-43	
	Number of Meteors	Path Length	Number of Meteors	Path Length	Number of Meteors	Path Length
<25	34	63	17	88		
25-30	56	84	59	114	12	103
31-36	27	97	62	130	26	158
37-43			32	137	23	161
43+					19	186

Table I shows the results. It will be noticed that for a given geocentric velocity the average path length increases almost but not quite so rapidly as the heliocentric velocity. It is apparent also that, in general, for a given heliocentric velocity, the path length increases rapidly with the geocentric velocity. This evidence is decisively in favor of the fictitious lengthening of path, and against the reality of the high heliocentric velocities.

3. We have said that since practically all the meteors in the catalogue were observed before midnight, those coming from near the apex had relatively long and flat paths, and those coming from near the anti-apex had steeper and shorter paths. For a given geocentric velocity, meteors coming from near the apex had lower heliocentric velocities. Hence, for a given geocentric velocity, meteors with low heliocentric velocities should have had higher points of appearance and disappearance.

If we consider the second viewpoint, that the high heliocentric velocities are due to a fictitious lengthening of the path, a given geocentric velocity in the table would represent higher heliocentric values for greater lengthening and lower real geocentric values. Hence, if there is fictitious lengthening, higher heliocentric values should correspond to higher points of appearance and lower points of disappearance.

Here we have another method of testing the reality of the high heliocentric velocities. If the velocities are real, the lower heliocentric velocities should correspond to greater heights for appearance and disappearance in the atmosphere. If the high values are due to a fictitious lengthening of the path, the lower heliocentric velocities should correspond to low heights of appearance and greater heights of disappearance. In other words, the heights of appearance give us a distinction between the real and the fictitious velocities. The heights of disappearance do not.

Maltzev, for another purpose, combined the meteors of the catalogue into three groups according to heliocentric velocity and into seven groups according to geocentric velocity. His table is found in *Monthly Notices of the Royal Astronomical Society*, Vol. 90, Number 5, March, 1930, page 573. One of Maltzev's groups contains only a single meteor. Combining the other six groups into three groups, we obtained the results shown in Table II.

TABLE II

RELATION BETWEEN HELIOCENTRIC VELOCITY AND HEIGHTS OF APPEARANCE OR DISAPPEARANCE FOR METEORS OF THE SAME GEOCENTRIC VELOCITY

APPEARANCE

Geocentric Velocity	Heliocentric Velocity Less than 22 mi.		Heliocentric Velocity 22-31 mi.		Heliocentric Vel. Greater than 31	
Mi/sec	Number	Height	Number	Height	Number	Height
6-18.5	19	52.1	73	66.6	26	81.0
19-30.5	11	67.5	62	77.8	99	92.9
31-43	4	77.4	8	77.8	63	92.3

DISAPPEARANCE

Geocentric Velocity	Heliocentric Velocity Less than 22 mi.		Heliocentric Velocity 22-31 mi.		Heliocentric Vel. Greater than 31	
Mi/sec	Number	Height	Number	Height	Number	Height
6-18.5	19	27.6	75	28.5	24	30.4
19-30.5	11	36.4	61	32.5	99	26.6
31-43	3	64.0	10	43.9	65	34.9

It is evident that with an increase in heliocentric velocity, the height of appearance increases greatly, indicating that there is a fictitious extension in the path length. For disappearance, we find on the whole a decrease in the height with an increase in heliocentric velocity, but the difference is not so marked as for appearance. The effect on disappearance is, as we have said, not a distinguishing feature.

The Table II figures on height of appearance are strong evidence for fictitious lengthening of the paths in the catalogue.

4. The preceding tests all indicate that the majority of paths in the catalogue are fictitiously extended. Hence, where both short and long paths are available for the same meteor, the shorter paths should be used in determining the velocity.

The following are meteors for which heliocentric velocities can be computed from both short and long paths of the same meteor.

Meteor	Long Path		Short Path	
Sept. 23, 1910	61.2 m/s	Hyperbolic	24.0 m/s	Elliptic
Mar. 14, 1905	32.4 "	"	21.0 "	"
Jan. 12, 1879	25.5 "	Elliptic	17.6 "	"
April 2, 1891	35.7 "	Hyperbolic	25.4 "	"
April 2, 1891	38.4 "	"	18.5 "	"
Aug. 17, 1921	32.5 "	"	20.4 "	"

In every instance, the shorter path yields an elliptical velocity. In one instance, the longer path also yields an elliptical velocity. As the shorter paths should be used for determining the velocity, the figures indicate that all of these meteors were members of our solar system.

5. Harvard work with the reticle and telescope indicates that the fainter meteors are mostly extra-solar, but the percentage of extra-solar decreases as we go to brighter magnitudes. This suggests that the percentage of extra-solar meteors is very small for even the faintest meteors recorded in the catalogue.

The point can be tested by averaging the heliocentric velocities separately for the faintest and the brightest meteors in the catalogue. The Harvard result suggests that the percentage of extra-solar meteors cannot be the same for detonating meteors as for meteors fainter than Venus, unless it is negligible for both magnitudes.

The average velocity was found for the catalogue meteors less than or equal to Venus in brightness (93 in number), and for the detonating meteors (84 in number). For the 93 fainter meteors, the average heliocentric velocity was found to be 34.3 miles per second. For the 84 detonating meteors, the average heliocentric velocity was found to be 34.4 miles per second. The difference is negligible, suggesting that the percentage of extra-solar meteors is negligible in both groups.

University of Iowa, March 20, 1937.

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD, President, *and* H. H. NININGER, Secretary

A Tentative Identification of Lines in a Meteor Spectrum*

By JOHN S. HOPKINS

ABSTRACT

A rotating meteor spectrograph, designed to increase the exposure times possible in the photography of meteor spectra, is described. A spectrum obtained with this instrument is shown and a table of the wavelengths as now identified for the lines is given. The meteorite is identified as a stone (an aërolite).

Early in the summer of 1934, tests were made at the Frank P. Brackett Observatory of various photographic emulsions, in preparation for attempts at the photography of meteor spectra during the annual shower of Perseids near the middle of August of that year. Eastman Portrait Panchromatic (on film) was chosen for its good speed, combined with highly uniform coverage from red to

*The substance of a paper read at the Fourth Annual Meeting of the Society, University of California at Los Angeles, June 23 and 24, 1936.

violet. A fairly red-sensitive emulsion was desired, because in Millman's investigation,[1] the wavelengths previously identified by calculation range up to λ5500, and it was desired to extend this at least 500 angstroms farther, thus to include at least the *D* lines of sodium.

The rotating meteor spectrograph was next constructed. The object of this piece of apparatus was to follow the meteor in its general direction and speed across the sky and thereby to increase the effective exposure upon the plate. Figure 1 shows this instrument as merely a frame eight inches square, capable of being rotated about a horizontal axis. Mounted on this frame were four cameras each covering a cone of sky of about 30° in good definition. These cameras were equipped with lenses varying in aperture ratio between *F*. 2.7 and *F*. 4.5 and having focal lengths from 12 cm. to 15 cm. Through double reduction gears, the entire

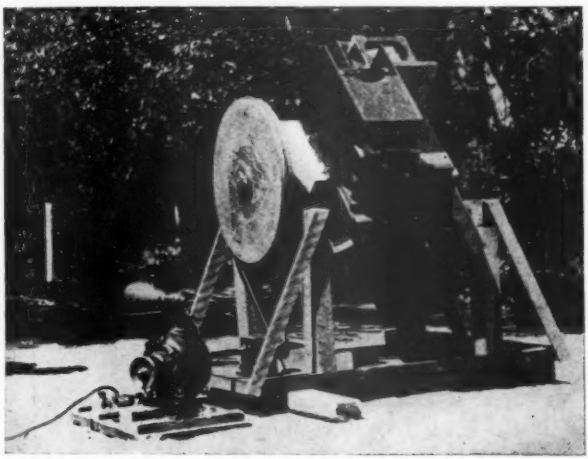

FIGURE 1
A ROTATING METEOR SPECTROGRAPH WITH FOUR PRISM-CAMERAS

frame and cameras were driven at an angular velocity of about 30° per second, giving a sweep velocity at a height of 70 miles of about 35 miles per second, which is in the vicinity of the average speed of these meteors. Each camera was equipped with an objective prism, two of 25° and two of 30°. These angles represent simply those prisms which could be cut most efficiently from a block of dense flint glass which was readily available from the optical shop of Mr. Fred C. Henson in Pasadena.

Dr. Walter T. Whitney, who designed the spectrograph, proceeded with Mr. Elvin Genung to Table Mountain, twenty miles due north of the Brackett Observatory. There, at the Smithsonian Solar Observatory, the instrument was set up with its axis horizontal and normal to a perpendicular plane through the average azimuth of the radiant. All of the cameras were collimator-focused at the Observatory in Claremont, and the final stellar focusing was done at the field

[1] "An Analysis of Meteor Spectra," by Peter M. Millman, *Ann. Astr. Obs. Harvard Coll.*, **82**, No. 6, pp. 113-146, 1932: see Fig. 1, p. 133.

station. Plates (films) were exposed for an hour each. After they were inserted and the slides drawn, each plate was exposed for a minute or so on some convenient and fairly bright star whose spectrum would provide a calibration for that plate. Visual watch was kept for any very bright meteors, and the one which was photographed was duly timed. This set of plates was developed in aged "*D*-11" developer.[3] The meteor was traveling at some speed other than that of the camera field, and its spectrum is spread across the area of the field which is in good definition. The lines of the spectrum are about three inches long, and right in the center of the plate. The direction of travel of the meteor was almost normal to the dispersion, and the calibration star spectrum is only a quarter of an inch or so away from the meteor spectrum.

FIGURE 2

A METEOR SPECTRUM PHOTOGRAPHED WITH THE ROTATING METEOR SPECTROGRAPH ILLUSTRATED IN FIGURE 1

A star spectrum appears beside the meteor spectrum and serves for calibration of the plate. The red end of these spectra is to the right. (Figures 1 and 2 are reproduced with the kind permission of the Astronomical Society of the Pacific: see *Publ. A.S.P.*, **46**, Plates XI and XII, opp. pp. 278 and 279, 1934.)

As there are no clear, sharp lines in this spectrum, various means have been tried to improve its contrast and measurability. Figure 2 is about a five-times enlargement. The lines in the star spectrum were suspected of being the Balmer series of hydrogen, but, at first, comparator measurements failed to substantiate this suspicion. To assist in the identification of the lines in the spectrum of the comparison star, spectra were taken of various laboratory sources and of a series of stars ranging in spectral class from A0 to M0. The spectrum of the calibration star was almost identical with that of Vega (α Lyrae, class A0). These later

[3] *Elementary Photographic Chemistry*, Eastman Kodak Company, p. 58, 1934. "*D*-11" is a developer chiefly for Process plates and films, which we have found to give good contrast and density in a fairly short time and without too much fog and grain.

spectra were taken with the same kind of plates and with the same prism as were initially employed, but with a different lens of the same focal length. It was then ascertained that the red limit of these plates was below λ6563 for a faint continuous background and that what seemed to be the first line of the series was just the rather sharp cut-off of the film in the red. The lines were then found to be the five lines of the Balmer series, including $H\alpha$ and $H\epsilon$. From the first, second, and fourth of these, the Hartmann constants were found to be: $n_0 = -0.8270$, $\lambda_0 = 2352.2$, and $c = 3396.3$. These check the remaining two lines within 5A.

An open-scale plot on accurate graph paper was then prepared from the comparator readings of the star and meteor spectra, as suggested by Millman.[3] In the star spectrum, the positions for the persistent lines of Ca and Na were plotted also from their calculated positions. These two spectra were then superposed and adjusted to a fit for λ5893 and λ3934. Working then from the *D* lines as standards, we calculated wavelengths for other lines in the meteor spectrum. These wavelengths were calculated also by considering the *D* lines as coincident with others of the meteor spectrum, but the best choice graphically was likewise the best mathematically. Table I gives these wavelengths, wavelengths of elements with which a coincidence is thought possible, the average or blended wavelength of the possibilities, and the difference between the measured and blended wavelengths. Lines marked *p*, are the *persistent* lines of an element, and those marked *P*, are the *most sensitive* of the *persistent* lines of that element. The lines in the meteor spectrum are so broad and shaded that no attempt was made to measure their edges, and it was thought that all lines could be considered blends of any lines within ±20A.

TABLE I

Wavelength (measured)	Wavelength (possible choice from tables)	Wavelength (blended)	Diff. of Wavelength (measured *minus* blended)
7032 A.	7017 Co; 7028 Co; 7053 Co	7033 A.	— 1 A.
6108	6104 Li; 6103 Ca; 6122 Ca	6110	— 2
5893	5890 Na, *P*; 5896 Na, *p*	5893	0
5755	5751 Mo	5751	+ 4
4628	4607 Sr, *P*	4607	+21
4456	4456 Ca, *p*; 4457 Ca, *p*	4456	0
4225	4227 Ca, *P*	4227	— 2
4030	4031 Mn, *P*; 4033 Mn, *p*; 4034 Mn, *p*	4032	— 2
3933	3934 Ca, *P*	3934	+ 5
3841	3829 Mg, *p*; 3832 Mg, *p*; 3838 Mg	3833	+ 8

The identification of λ5755 seems to be rather weak, because A. S. King[4] and I. and W. Noddack[5] find only small amounts of Mo present in meteorites and those amounts principally in irons (siderites). λ4628, likewise, is uncertain of identification, principally because of the large deviation of +21A.

It seemed possible that, if the exact coincidence were made at λ3933 instead of λ5893, the large number of positive deviations might be reduced, and a better fit obtained at all points, except, of course, those where the deviation was already zero. The algebraic sum of the deviations in Table I is +31A., making the average deviation +3.1A. The difficulty is, of course, that the wavelength is changing so rapidly with respect to the comparator readings near the end of this prismatic spectrum, that the necessary shift for a coincidence at λ3933 might seri-

[3] *Op. cit.*, footnote (1), p. 118.
[4] *Astrophys. Jour.*, **84**, 510, 1936.
[5] *Naturwissenschaften*, **18**, 757, 1930.

ously displace all the lines in the red. This condition would follow from a consideration of the slope of the dispersion curve for this prism. This procedure was tried, but the shift was so great in the red that all coincidences were seriously displaced. The only help produced was in the violet, and for the line λ6108, which could be identified now with a Co line as closely as it could formerly be identified with the Li and Ca lines. Even with this new and close coincidence, the algebraic sum of the deviations became —86A., thus making the average deviation —8.6A., or almost three times that for Table I, and of opposite sign.

In view of this preliminary study, it seems reasonably apparent that this meteorite was a stone (an aërolite), since no evidence of the presence of iron was found in the spectrum of the meteor which it produced.

I wish to thank Dr. Whitney for his patience and guidance, the Smithsonian Institution, and in particular Field Director A. F. Moore of its Table Mountain Station, for help and for the use of buildings and equipment, and Mr. P. A. Williams of the Eastman Kodak Agency in Los Angeles, for very generously lending us the lenses used in the cameras.

Frank P. Brackett Observatory, Pomona College, Claremont, California

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Advance Notice of the Fifth Annual Meeting of the Society

The Fifth Annual Meeting of the Society will be held in conjunction with the one hundredth convention of the American Association for the Advancement of Science and its Western Divisions at Denver, Colorado, on Tuesday, June 22, and Wednesday, June 23, 1937. There will be two sessions a day, mainly for papers, one in the morning at ten o'clock and another in the afternoon at two o'clock. At six o'clock on Wednesday evening, June 23, there will be a dinner for members and their guests at the Denver Athletic Club. All the scientific sessions will be held in the Colorado Museum of Natural History, which will serve as headquarters for the meeting.

As usual, a roll call of committees will be a feature of the meeting. Chairmen are accordingly requested either to bring with them or to send to the Secretary, reports of the activities of their committees. A meeting of the Committee on Terminology is definitely scheduled.

All members of the Society who desire to present papers or reports at the meeting, regardless of whether they will be able to attend it or not, are invited to do so, but should have the titles of their contributions in the Secretary's hands, *if possible by May 1 and by May 15 at the latest.* Every communication intended to be read at the meeting should be accompanied by an *abstract,* designed for publication in the *C.S.R.M.,* especially if the original is too long or otherwise unsuitable for inclusion herein.

It is hoped that there will be a good attendance at the meeting, the scientific sessions of which will be open to the public and at which visitors will be welcome.

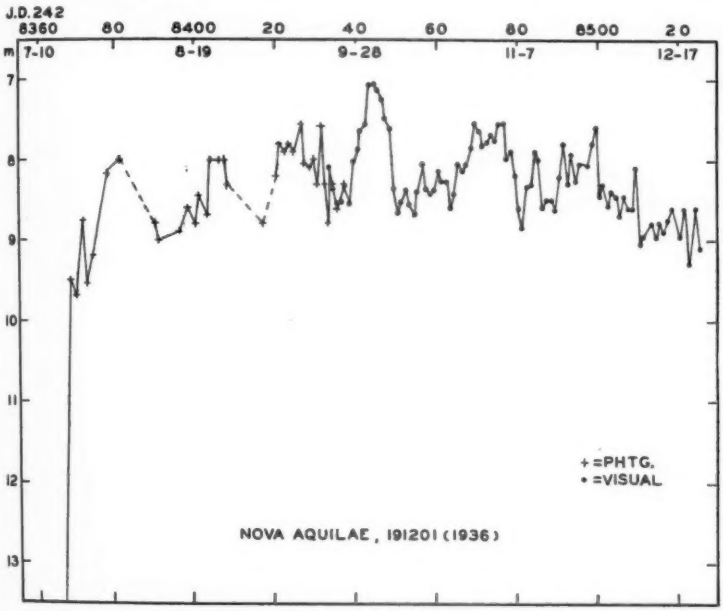
Secretary's Office: Nininger Laboratory, 1955 Fairfax Street, Denver, Colorado
Editorial Office: Department of Astronomy, University of California at Los Angeles

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

Nova Aquilae, 191201: Although the first of the two novae discovered by Tamm in the constellation of Aquilae in 1936, was not detected until September 18, a number of earlier photographic observations are available at several observatories, including Sonneberg, Harvard, Maria Mitchell, and the California Institute of Technology. Miss Harwood found the Nova to be about magnitude sixteen on July 17, probably at or near the time of the actual beginning of the rise. Two



days later the star increased in brightness to magnitude 9.5. A plot of the early photographic observations and the visual observations made after discovery indicates a number of marked fluctuations of approximately a magnitude each at mean intervals of about twenty-three days. Maxima occurred near the following dates:

July 23	8.0	(Phtg.)	Oct. 3	7.1	(Vis.)
Aug. 22	8.0	(Phtg.)	Oct. 30	7.6	(Vis.)
Sept. 13	7.7	(Phtg.)	Nov. 22	7.8	(Vis.)

Several other minor fluctuations took place; in particular a sharply defined maximum near November 12, visual magnitude 7.9. In appearance the light curve closely resembles that of Nova Pictoris, 1925, and, in some respects, that of Nova

Herculis, 1934, in its earliest stages. The light curve is shown in the accompanying figure, compiled from nearly 500 observations communicated to the A.A.V.S.O. headquarters, and from the published material, particularly that of the Japanese observers.

*Nova Sagittarii, 1802*34: Quite different in appearance is the light curve of Nova Sagittarii, No. 16, discovered by S. Okabayshi, of Kobe, Japan, on October 4, 1936, when compared with that of Nova Aquilae, 191201. In a little more than a month after the time of discovery the Nova had decreased from the magnitude 4.5 to fainter than the eighth magnitude, the decline during the first few days being decidedly rapid. No information concerning the Nova before discovery is available, but it would appear that, when compared with other light curves of novae which have behaved in a similar manner, it could not have been much brighter than the fourth magnitude for many days without being detected by some observer, particularly some one situated in the Southern Hemisphere.

Another Eclipsing Variable of Very Long Period: The hitherto presumably irregular variable, VV Cephei, discovered by Miss Cannon in 1907, is now definitely shown to be an eclipsing star with the second longest known period; exceeded only by ε Aurigae.

Miss Cannon found an absorption spectrum of M2 and in addition, bright lines of hydrogen and other substances. When the star was discovered, she suggested that the spectrum was composite. Spectrograms taken at various observatories have shown a variable radial velocity and Dr. W. H. Christie offered evidence of a spectroscopic period of eighteen or twenty years for the absorption spectrum of Class M. Recently, Dr. D. B. McLaughlin stated that in 1936 emission lines were absent from the spectrum and he suggested that the star might be an eclipsing system, similar to Zeta Aurigae. He also noted that the star was unusually faint from March to October, 1936.

Dr. S. I. Gaposchkin, from an examination of more than 2500 Harvard plates covering an interval of over forty years, has determined a periodic light curve which, when studied in connection with the radial velocities observed elsewhere, reveals the following salient facts:

Observed minima	1895, 1916, 1936
Period	7450 days, or 20.4 years
Photographic magnitude range	6.6-7.4
Duration of eclipse	490 days
Duration of totality	450 days
Ratio of the radii of components	0.01
Inclination of orbit	52°
Eccentricity of orbit	0.25
Ratio of masses	0.8
Masses of components	M = 44.5 ⊙, B = 35.4 ⊙

(the M component is therefore the most massive of any known in an eclipsing system)

The M (red) supergiant component has a radius of about 1100 solar radii; it is about three times the size of Alpha Herculis and the largest star known.

The photographic range in light apparently greatly exceeds the visual range. The difference may be due to the great disparity in color of the two components as observed visually; a feature also noted in Zeta Aurigae. During minimum light, the M component appears to vary appreciably, thus causing an irregularity in the curve when the blue component disappears during eclipse.

The visual observations of this star have not been satisfactory, probably due, in part, to the red color of the bright M component. Some observed light curves

suggest a period of about a year, but the question of parallactic angle may be involved to a degree. Photographic observations in yellow and in blue light are doubtless preferred over visual estimates for stars of such small amplitude.

This interesting variable is presumably at minimum at the present time, and before long is due to rise to maximum. Perhaps other stars, such as Alpha Herculis, should also be examined in order to ascertain whether or not they, too, are eclipsing stars of exceedingly long period, which because of strong color effect have remained undetected.

J. Ernest G. Yalden: The A.A.V.S.O. has suffered a genuine loss in the death on February 22, of J. Ernest G. Yalden, a Life Member and Patron of the Association. Born in 1870, in London, England, Mr. Yalden came to America in his youth. After graduating from the Engineering School of New York University, he became associated with the Baron de Hirsch Trade School, of which he was organizer and first Superintendent; a position which he held until 1930, when poor health necessitated his retirement.

Mr. Yalden was an active member of the Association since 1918, when the appearance of Nova Aquilae, No. 3, aroused his keen interest in astronomy. He had erected at his home in Leonia, New Jersey, a model dome of his own design to house his 4-inch refracting telescope. He had served on two of the most important committees of the Association; the Chart and the Occultation committees; having acted as chairman of the latter committee for a number of years.

He was an expert engineer and an able computer. He wrote many articles on the application of mathematics in industry, as well as on the design of domes and on methods for predicting occultations. He was an authority on Sun Dials.

Mr. Yalden served as President of the A.A.V.S.O. during the years 1925 to 1928. He was a man of distinguished and charming personality and his presence at the future meetings of the Association will be greatly missed.

Observations: Fifty-four observers have contributed observations during the month of February to the number of 3839. Mr. Robert Fleischer, a student at Harvard University, has contributed for the first time. A list of observers, together with the number of observations made by each individual, follows:

Name	Vars.	Observations	Name	Vars.	Observations
Ahnert	43	277	Holt	51	93
Atchison	1	1	Houghton	66	175
Baldwin	71	96	Houston	131	451
Ballhaussen, Miss	37	54	Howarth	9	9
Bappu	36	81	Humbert	8	14
Blunck	12	13	Jones	84	364
Bouton	72	125	Kanda	1	10
Brocchi	16	23	Kawai	1	31
Cameron	15	28	King	2	2
Carpenter	77	89	Kirkpatrick	15	41
Chartier	18	29	Kitchens	11	13
Dafter, Mrs.	10	57	Knott	2	2
Diedrich	1	1	de Kock	32	140
Ellis	18	23	Kohman	3	3
Ensor	48	100	Kozawa	15	170
Fairbanks	12	14	Loreta	122	281
Fleischer	3	3	Marshall	1	6
Focas	62	176	McLeod	16	31
Franklin	13	21	McNabb	1	3
Hartmann	127	240	Murphy	10	16
Herbig	29	37	Peltier	120	131
Hiett	24	62	Rosebrugh	28	93

Name	Vars.	Observations	Name	Vars.	Observations
de Roy	10	64	Smith, L.	14	14
Scherr	4	19	Treadwell	10	20
Sill	10	10	Ushiyama	4	4
Smith, F. P.	9	14	Webb	42	49
Smith, F. W.	1	3			
Smith, J. R.	9	9	54		3839

March 11, 1937.

Comet Notes

By G. VAN BIESBROECK

COMET 1937 *c* (WILK-PELTIER).—A fairly bright comet was found shortly after sunset by A. Wilk at Cracow (Poland) on February 27, and independently a few hours later by L. C. Peltier at Delphos (Ohio). The first information about this discovery came to the various observatories in the form of the following telegraphic message from T. Banachiewicz, director of the Cracow Observatory:

Comet Wilk 1937 Feb. 27.7674 U.T. $0^h\,35^m\,17^s$ $+19°\,22'$ Magnitude 7.

The same evening L. C. Peltier sent to the writer the following message:

"Seventh magnitude nebulous object $0^h\,35^m$, $+20°$, too low to verify here."

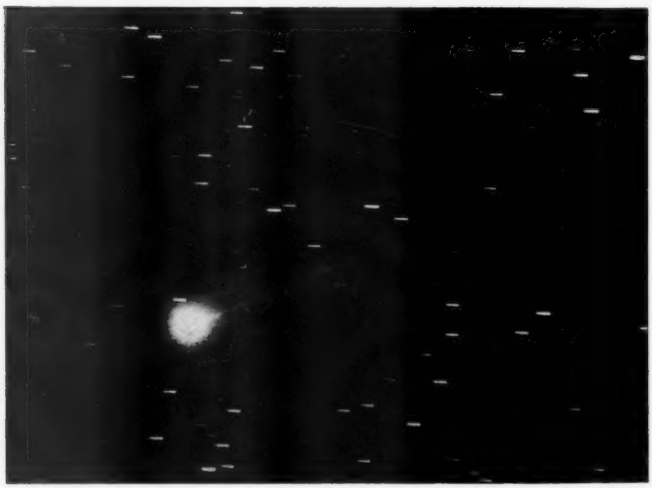


FIGURE 1

COMET 1937 *c* (WILK-PELTIER) AS PHOTOGRAPHED ON MARCH 2, 1937

The object will therefore bear the name of the same team of discoverers as that which was responsible for Comet 1925 *k* (Wilk-Peltier). It was followed at several observatories and already on March 2 the Harvard Observatory published a set of elements computed by Whipple and Cunningham from measures on three successive nights at Oakridge. Independent computations by A. D. Maxwell

(Michigan) and C. H. Smiley (Berkeley) confirmed the orbit which is defined by the following elements:

	Whipple and Cunninghain	Smiley	Maxwell
Perihelion passage U.T.	Feb. 21.7280	Feb. 21.84800	Feb. 21.84934
Node to perihelion	32° 9′.4	32° 5′ 22″.2	32° 5′ 14″.1
Longitude of node	57 3.5	56 53 21.3	56 52 56.5
Inclination	25 57.5	26 22 14.1	26 22 47.5
Perihelion distance A.U.	0.61975	0.6213784	0.6214099
Dates used	Feb. 28	Feb. 28	Feb. 28
	Mar. 1 and 2	Mar. 6 and 10	Mar. 5 and 10

The following ephemeris computed from the last set of elements shows the future course of the comet:

1937 0^h U.T.	α h m s	δ ° ′	—Distance from— Earth	Sun	Mag.
April 1	4 15 13	+68 52.4	0.583	1.005	10.3
5	5 52 39	71 18.2			
9	7 33 23	70 14.0	0.607	1.127	10.9
13	8 48 57	66 32.0			
17	9 38 27	61 40.5	0.671	1.250	11.6
21	10 11 8	56 35.0			
25	10 33 58	51 40.6	0.769	1.373	12.3
29	10 50 50	47 7.7			
May 3	11 3 59	42 58.9	0.892	1.495	13.0
7	11 14 40	39 13.9			
11	11 23 43	35 50.7	1.036	1.616	13.5
May 15	11 31 36	+32 47.2			

I have added the expected magnitude assuming $8^M.0$ for March 8 and a variation inversely proportional to the 4th power of the distance from the sun.

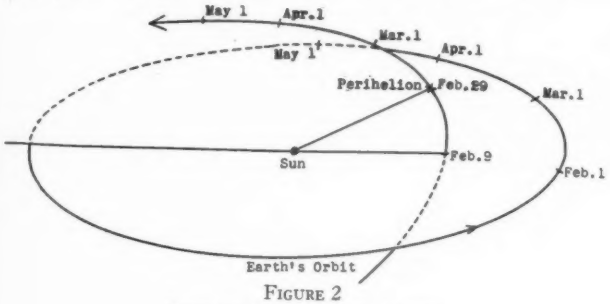


FIGURE 2
ORBIT OF COMET WILK-PELTIER

In the beginning of April the comet is visible during the whole night in the constellation of Camelopardus. Later is crosses into Ursa Major but the brightness drops quite fast. The comet was discovered near maximum brightness and at that time it showed a fuzzy nucleus surrounded by a coma about 2′ in diameter and a sharply defined tail in a direction opposite to that of the sun. As the comet came nearer to the earth in March the apparent size of the coma increased. On March 14 I estimated the diameter as 6′ but the brightness had dropped considerably and the tail was only faintly visible. Figure 1 shows the appearance of the comet from a plate exposed by the writer on March 2. On the original plate the tail extends to more than a degree from the nucleus.

Figure 2 illustrates the course of the comet relatively to the earth and the sun. It is seen that it was found shortly after it emerged from the sun's rays, that it crossed the plane of the ecliptic on February 9 and that it will be well placed for some time to come. However, the increasing distance will soon reduce it to a faint object.

The other comets of this year have been followed further: PERIODIC COMET 1937 *a* (DANIEL) was recorded by the writer on March 2 and 7 as a very faint small nebulous object of magnitude 16; close to the position indicated by the ephemeris on p. 157 of the March issue.

COMET 1937 *b* (WHIPPLE) has been well observed and the expected rise in brightness confirmed. I have estimated the total brightness as follows on the Harvard scale:

	M		M
Feb. 17	10.5	Mar. 12	9.3
Mar. 11	9.8	Mar. 14	9.2

This would make the object brighter than is indicated by the ephemeris on p. 157.

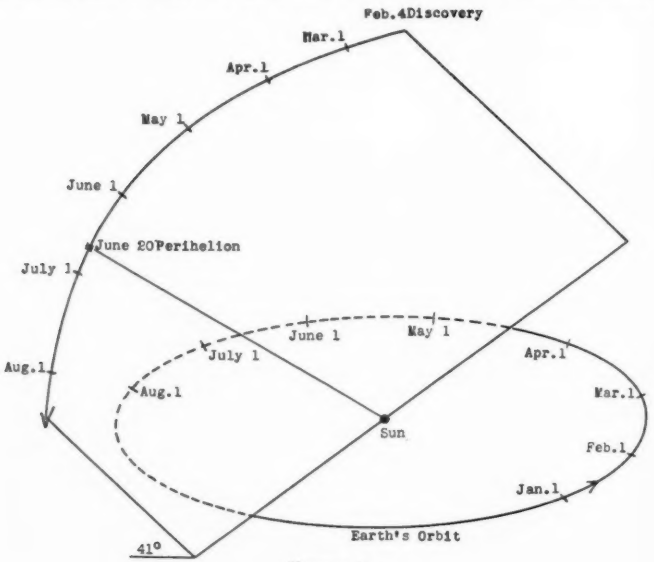


FIGURE 3
ORBIT OF COMET WHIPPLE

The tail has also become more conspicuous and it will probably be visible even in small telescope in April. Dr. A. D. Maxwell, discussing the positions from February 4 to February 19, has deduced an improved set of elements which do not differ materially from those given on p. 157.

Perihelion passage	1937 June 20.47484 U.T.
Node to perihelion	108° 22′ 57″.1
Longitude of node	127 37 20.9
Inclination	41 28 22.1
Perihelion distance	1.721085 astronomical units

From these I have computed the continuation of the ephemeris (p. 157):

1937 0^h U.T.	α h m s	δ ° ′	—Distance from— Earth	Sun	Mag.
Mar. 28	14 10 24	+54 52.1	1.363	2.038	9.0
April 1	12 44	56 5.0			
5	14 44	57 10.2	1.344	1.985	8.8
9	16 24	58 7.3			
13	17 47	58 55.6	1.331	1.937	8.7
17	18 54	59 34.7			
21	19 51	60 4.3	1.321	1.892	8.6
25	20 41	60 24.4			
29	21 27	60 34.7	1.312	1.852	8.5
May 3	22 15	60 35.2			
7	14 23 8	+60 25.8	1.304	1.816	8.4

The magnitudes have been established under the assumption that on March 12 the magnitude was 9.3. The apparent path is near the boundary of the constellations of Boötes and Ursa Major. The path in space is shown in Figure 3 which indicates the relation of the comet to the earth and the sun through perihelion passage. The comet will remain visible for many months and become accessible in small instruments, but naked-eye visibility is hardly to be expected.

The search for the expected PERIODIC COMET GRIGG-SKJELLERUP has not been successful so far. The region was examined by the writer in the early part of March but no indication of the presence of this object could be detected. The increasing brightness ought to bring the object to light before long. The search ephemeris is continued here from the *Handbook of the British Astronomical Association* for 1937.

	α h m	δ ° ′
Mar. 24	5 42.5	— 0 53
April 1	5 54.0	+ 0 46
9	6 7.7	2 31
17	6 24.7	41 24
25	6 44.8	+61 28

Another periodic comet which has escaped detection this year is 1925 II (SCHWASSMANN-WACHMANN). Exposures on the region, showing stars down to magnitude 16 obtained here on March 17 did not reveal any trace of the object.

Williams Bay, Wisconsin, March 20, 1937.

Notes from Amateurs

The Amateur Astronomical Society of New Haven

The Amateur Astronomical Society of New Haven held its monthly meeting in the Lecture Room of the Yale Observatory on March 20.

Several matters of importance were brought up to add to and increase the activities of the several groups working independent of the parent society, such as the telescope making, the observing, and calculating groups, each of which has its respective chairman.

Mrs. Rademacher, chairman of the Observing Group, presented on the blackboard and enumerated the various astronomical events to occur before our next meeting, calling special attention to several important events.

Mr. Anyzeski then addressed the society on "Meteors" and by means of elab-

orate charts and diagrams together with several specially constructed small models gave a very clear, complete, and comprehensive account and description of meteors, their size, distance, speed, and composition, and the value of observing them.

He cited circumstances connected with the falling of some unusually large meteors, particularly one weighing 50,000 tons that fell in Siberia which destroyed a forest of an area of 50 miles in which all trees were left flat on the ground pointing away from the center, and the large meteor that fell in Arizona leaving a large crater to mark its location. The average speed of meteors he stated was 26 miles per minute with a top speed of 45 miles per minute. He also mentioned the valuable work that the aeroplane is doing to locate many unknown large craters. Mr. Anyzeski's talk was very instructive and much appreciated by all present.

The speaker at our April 24 meeting will be Professor Stevens of Yale University whose subject will be "Astronomy in 2000 B.C."

FRANK R. BURNHAM, *Secretary.*

Amateur Astronomers Association with headquarters at the American Museum of Natural History, New York City, is following a schedule of meetings for March and April, as follows:

March 3, address by Dr. A. M. Skellett, Bell Laboratories.

March 17, address by Dr. W. J. Eckert, Columbia University.

April 7, address by Dr. Theodore G. Mehlin, Yale University Observatory, on the subject "Methods in Astronomical Photography."

April 21, address by Mr. Wagner Schlesinger, Fels Planetarium, Philadelphia, Pennsylvania.

The Cleveland Astronomical Society

With every seat taken our society met at 8:00 P.M., Friday, February 26, at the Warner and Swasey Observatory. Dr. J. J. Nassau, director, opened the meeting with a report on finances. The treasury is well filled with an amount of money which is a very unusual situation for an astronomical society. The membership is active and seems to be growing. Our success is due to the untiring efforts of Dr. Nassau always to have a good program and speaker at every meeting.

The subject this month was Comets—The Strange Solar Family. The speaker, Dr. S. W. McCuskey, began his astronomical career at Case and during the past two years has been at Harvard where he received his doctorate. We were all glad to have him with us again in Cleveland. Slides illustrated the lecture which was very interesting.

After the lecture there was an informal discussion for the telescope makers, and the usual mirror clinic.

DON H. JOHNSTON.

14 Lincoln Drive, Cleveland, Ohio.

Note on the Diameters of Large Sun-Spot Umbrae and Penumbrae

Dr. Charles E. St. John published in the *Astrophysical Journal*, 1913, Vol. 37, pp. 322-353, a paper entitled, "Radial Motions In Sun-Spots," wherein a table is given containing the diameters of eleven sun-spot umbrae and penumbrae, in millimeters as observed on a solar image 170 mm in diameter. The mean diameters of umbrae and penumbrae being respectively 1.1 mm and 3.0 mm.

I, being an amateur astronomer whose audacity at times prompts him to compare the results of his own data with those of the professional astronomer, undertook an investigation of my drawings of large sun-spot umbrae and penumbrae.

The method of procedure in drawing up the following table was:

1. The selection of the largest spots upon the sun.

2. Computation of the diameter of the large scale solar image (upon which measurements of umbrae and penumbrae were made) from the relative distances between easily distinguished sun-spots on the diagrams of the entire solar disc (general survey of solar disc with a magnification of 28×, the diameter of this image being usually 156 mm) and the distances between the same spots on the large scale diagrams.

3. Correction of umbral and penumbral diameters to a solar image of standard diameter—here I have used Dr. St. John's figure of 170 mm for the sake of comparison.

The following table shows my corrected measurements to the nearest tenth of a millimeter:

The sun-spot numbers are arbitrary and are included merely to show measurements of the same spots on different dates.

Spot No.	Date and Time 1936		Diameter of Umb.	Pen.	Spot No.	Date and Time 1936		Diameter of Umb.	Pen.
1	Feb. 11	11:00 a.m.	.7	2.1	7	May 12	10:30 a.m.	1.7	3.6
2	11	11:00 a.m.	1.8	3.2	7	13	12:10 p.m.	1.9	3.1
3	11	11:00 a.m.	1.1	2.5	8	16	11:00 a.m.	1.5	2.9
1	Feb. 12	11:00 a.m.	.7	2.9	8	17	10:50 a.m.	1.5	3.6
2	12	11:00 a.m.	1.0	3.1	8	18	10:25 a.m.	1.1	2.3
3	12	11:00 a.m.	1.0	1.9	8	18	11:25 a.m.	.9	2.3
1	Feb. 15	12:30 p.m.	.9	2.6	8	19	9:50 a.m.	1.5	4.0
3	15	12:30 p.m.	.9	2.6	8	20	11:25 a.m.	.7	2.9
4	Mar. 29	10:30 a.m.	.7	2.2	8	21	10:45 a.m.	1.1	2.4
5	29	10:30 a.m.	.7	1.8	9	25	9:45 a.m.	1.5	3.5
6	Apr. 20	9:35 a.m.	1.4	3.4	9	26	10:05 a.m.	1.2	3.5
6	23	10:40 a.m.	1.6	4.4	10	27	5:30 p.m.	1.6	3.3
6	24	10:00 a.m.	.7	2.1	10	29	10:35 a.m.	2.2	4.5
7	May 11	12:45 p.m.	2.1	3.1	11	June 7	10:10 a.m.	.9	2.7
							Mean	1.2	2.9

The mean values agree very well with Dr. St. John's; in fact, I expected a far greater deviation because of the great part played by the selection of spots.

Dr. St. John's values (not the mean) when plotted show a distinct variation in the diameter of penumbra with respect to a given umbra, that is an umbra of a given diameter does not possess a penumbra of a fixed diameter. However, Dr. St. John's values of variation are much smaller than mine.

GEORGE PATTULLO KIRKPATRICK.

36 Commerce Street, New York City, July 13, 1936.

General Notes

Dr. Max Talmey, a physician, a writer on astronomical subjects, and a linguist, delivered a lecture before the Linguistic Club of Yale University on March 8 on the subject "Some Aspects of an Adequate Auxiliary Language."

Dr. Daniel Buchanan, Dean of the Faculty of Arts and Science, University of British Columbia, will conduct two courses in astronomy in the Summer Session of the University of California at Los Angeles, June 26 to August 6, 1937, while Dr. Frederick C. Leonard, Chairman of the Department of Astronomy of

the University of California at Los Angeles, will teach a couple of astronomical courses in the Summer Session of the University of British Columbia, at Vancouver, July 5 to August 20, 1937.

Professor Ejnar Hertzsprung, director of the Leyden Observatory, was awarded the Catherine Wolfe Bruce Gold Medal for the year 1937, at a special meeting of the Astronomical Society of the Pacific held on November 28, 1936. The date of the formal presentation of this award has not yet been decided.

Dr. Harold Jeffreys, Lecturer in Mathematics and Reader in Geophysics at Cambridge University, Cambridge, England, has been awarded the Gold Medal of the Royal Astronomical Society for the year 1937, in recognition of "his researches into the physics of the earth and other planets and for his contributions to the study of the origin and age of the solar system."

L'Astronomie, for January, 1937, contains an extended, very interesting, and well illustrated account of the eclipse expedition from France to Russia for the purpose of observing the total eclipse on June 19, 1936.

The New Zealand Astronomical Society Bulletin, No. 24, recently received, is devoted to a report of the section for the observation of meteors, and includes the results of the work of the years 1932-34. The report was prepared by Mr. R. A. McIntosh.

The Astronomical Society of France this year is celebrating its fiftieth anniversary. The foundation meeting was held at the home of M. Flammarion in Paris on January 28, 1887. The object of the Society, then stated, was "to bring together isolated observers, centralize their work, permit instructive comparisons, and encourage the observers to continue in work so useful to progress."

Junior Astronomy News, for March, 1937, published by the Junior Astronomy Club with headquarters at the American Museum of Natural History, New York City, is marked as a special issue on the moon. The front cover contains a map of the moon and a list of sixty-five names relating to prominent features on the moon's surface. Five of the major articles are concerned directly with the moon. There are other papers also making a total of eleven pages of interesting reading for those whose interests lie in the realm of this the oldest of the sciences.

Notes from the Yerkes Observatory

Mrs. Cecilia Payne Gaposchkin of the Harvard College Observatory will give a course of lectures on fundamental photometry and variable stars at the Yerkes Observatory for six weeks, beginning about May 15.

The instruction in astronomy at the Yerkes Observatory and on the campus of the University of Chicago has now been completely revised. At the present time Dr. Kuiper lectures on *Statistics and Dynamics of Stellar Systems,* Dr. Chandrasekhar on the *Theory of Stellar Interiors,* and Dr. Van Biesbroeck on *Astrometry.* These lectures will continue through the summer quarter. Beginning October 1, Dr. Strömgren will lecture on *The Theory of Absorpton and Emission Power of Matter.* During the winter quarter of 1938 he will lecture on *The Theory of Stellar Atmospheres,* and this will be followed by a course on *The Theory of Interstellar Matter.* Dr. Morgan will lecture for three quarters on *Stellar Pho-*

tometry, and Dr. Struve on *Stellar Spectroscopy*. Courses at the Observatory will also include *Orbit Computations* by Van Biesbroeck, *Optical Instruments* by Moffitt or Ross, and *Physical Properties of the Photographic Plate* by Ross or Moffitt. On the campus of the University, Dr. Bartky is giving the regular instruction in *Celestial Mechanics, Planetary Perturbations*, and *Periodic Orbits*. Courses will also be given, beginning October 1, in *Descriptive Astronomy, Elementary Astrophysics, Variable Stars*, and *Interstellar Matter*.

Professor F. E. Ross, who has spent the winter at Pasadena, expects to return to Williams Bay on April 1. He plans to extend his work on proper motions with the Bruce photographic telescope.

Dr. C. T. Elvey, who has spent over a year at the McDonald Observatory in Texas, will return to Williams Bay for a part of the summer, and Dr. Seyfert will go to Texas, beginning about June 1.

Asteroid Names.—The work of two Americans being done in connection with asteroids has recently been recognized in the naming of two of the recently-discovered minor planets. They are, asteroid 1230, Riceia, named for Mr. Hugh S. Rice of the American Museum of Natural History, whose asteroid notes appear in POPULAR ASTRONOMY from month to month; and 1249, Rutherfordia, in recognition of the work of Mr. Irving L. Meyer of Rutherford, New Jersey.

Inquiry About an Ancient Astronomical Book

Professor Pio Emanuelli of Rome (R. University, Rome) desires to know whether there is in the Library of any American Observatory a copy of the following very rare book of the XVII century:

G. Schönberger.—*Sol illustratus ac propungnatus, in quo de omnibus iis, quae in coelo Solis accidunt, agitur et maxime motus stellarum solarium ostenditur, et liquiditas coeli monstratur.* Tr - 4°. Friburgi Brisgoiae, 1626.

This book is quoted, with this title, in: Houzeau-Lancaster,—*Bibliographie générale de l'Astronomie*, Vol. I, Pars I, p. 627, No. 3028.

A Tentative Theory of R Coronae Variation

The R Coronae stars form a small, well-known, but not very well-defined class of irregular variables. Prager's Catalog of Variable Stars for 1932 listed twenty-nine members of the class, but seven were listed as doubtful. It is needless to describe the behavior of typical members of this class, but some of the stars listed as R Coronae variables seem to partake more of the nature of Nova-like variables. RT Serpentis is an example of these stars.

A successful theory of R Coronae variation must explain the following facts:

(1) The light curve, with its rather sudden drop in light, its indefinite duration of minimum light, and its rise back to maximum.

(2) The fact that the maximum luminosity of an R Coronae star is, in typical stars, a definite limit, never exceeded, and nearly always reached.

(3) That most stars of this type have bright line spectra, which grow stronger as the star fades, and that in the cases where the stars have spectra without emission at maximum, bright lines appear as the star fades.

(4) That R Coronae variables range through the entire spectral sequence from B to K and R.

(5) That although the ranges of the R Coronae stars are rather large, there

is no evidence that the light changes are accompanied by temperature changes comparable to those accompanying the light changes of Cepheid and long-period variables. In other words, there is no evidence that the stars get cooler and redder as the light fades.

It has been discovered that nearly all of the R Coronae stars that are bright enough to have their spectra examined in some detail show very marked departures from the ordinary in chemical composition.

Merrill has shown that iron is extraordinarily abundant in the atmospheres of Z Canis Majoris (*Mt. Wilson Contr.* 334) and XX Ophiuchi (*Mt. Wilson Contr.* 444). Berman has shown that the atmosphere of R Coronae is 69 per cent carbon. Mrs. Gaposchkin finds that RY Sagittarii and SU Tauri have atmospheres very rich in carbon, with abnormal spectra of class G (*Harvard Bulletin* No. 903). S Apodis, RS Telescopii, and WX Coronae Austrinae are R stars.

This extraordinary abundance of elements other than hydrogen puts the R Coronae stars off of the mass-luminosity curve. Calculation shows that these stars are from one to three magnitudes too bright for their masses. As a consequence of this, the spectroscopic absolute magnitudes of the R Coronae stars, derived by the usual methods, will come out markedly too bright.

This feature concerning the R Coronae stars leads to the conclusion that the very bright absolute magnitudes which have been estimated for some of these stars must be reduced between two and three magnitudes.

The most accurate luminosity for an R Coronae star is that of W Mensae in the large Magellanic Cloud with a photographic apparent magnitude at maximum of 13.8. Using a modulus of 17.1, the absolute magnitude is —3.3 at maximum. R Coronae, for which chemical composition, effective temperature, and surface gravity are well known, owing to Berman's excellent work (*Ap. J.*, Vol. 81, No. 5), has an absolute magnitude of about —1. For the following stars, the writer gives his own rough estimates of absolute magnitudes, based on published material: RT Serpentis, spectrum cA8e, absolute magnitude —3; Z Canis Majoris, spectrum Beq, but iron extraordinarily abundant, absolute magnitude —3; AB Aurigae, spectrum Ae, absolute magnitude —0.5; XX Ophiuchi, a late Be spectrum with iron dominating the spectrum, absolute magnitude 0. These are rough estimates rather than definitive values for the luminosities at maximum light.

The spread in both luminosities and surface temperatures shows a good range in surface gravities and mean densities. Both of the last quantities must vary by factors of over 100 among the different R Coronae stars.

There are three ways in which a star can fade. In the first place, it can expand and cool off, according to Lane's law. Secondly, it may make some internal rearrangement; changing the model upon which it is built. Lastly, it may collapse to a white dwarf.

The first method is useless for explaining the R Coronae stars. The amount of expansion needed to reduce the brightness of these variables would lead to changes in spectrum and color far greater than any observed. At class G0 the amount of expansion needed to reduce the light of the star by one magnitude would cool the star enough to greatly increase the color index, and to change the spectrum from G to K. Among the B stars, the cooling effect of expansion would actually make the star brighter visually, by throwing energy out of the ultra-violet into the visual region of the spectrum. Therefore, if cooling by expansion were the cause of R Coronae variation, maximum light for XX Ophiuchi would be homologous to minimum light for R Coronae. The similarity of the behavior of

the emission spectra of the two stars, strengthening as the light fades, renders this interpretation absurd.

The second possibility, that the R Coronae stars fade by changing their internal construction, their diameters remaining constant, is also ruled out by the fact that a star fading through the large range of the average R Coronae, with a constant diameter would get very markedly cooler and redder.

Therefore, the collapse to a wite dwarf state is the one possible method for a R Coronae star to fade. The increasing strength of the emission spectrum as the light fades can be explained as follows. Bright lines in stellar spectra are produced by envelopes of transparent gases outside the stellar photosphere. The more extensive the envelope, the brighter the emission lines will be. Therefore, it would seem that in the R Coronae variables, when the star is fading and the photosphere and the matter inside the photosphere are collapsing, the stellar chromosphere and the gaseous envelopes are increasing in extent.

At minimum light, to an observer close enough to see details, an R Coronae variable would appear as a star surrounded by a shell of transparent gases, very much resembling a planetary nebula on a small scale.

Such a change as just described would account for the star fading several magnitudes without any cooling of the surface or great change in color. It will also account for the appearance of or strengthening of the bright lines in the spectrum as the star fades.

Chandrasekhar has recently shown that very massive stars, those stars where the ratio of the radiation pressure to the total pressure exceeds 0.0815, cannot become white dwarfs, but must continually brighten as they contract (*Monthly Notices of the Royal Astronomical Society*, Vol. 95, No. 8). This seems to set a definite upward limit to the luminosity of the R Coronae stars, at roughly absolute magnitude —4.

But what causes the star to collapse? The simplest theory is that the star experiences a temporary famine in available energy. Call the substance whose change supplies this energy "X." It may well differ from star to star. It must have a short life, or the downward slope of the light curve would be more gradual. Having a short life, it must be produced, under the conditions prevailing in R Coronae stars at maximum, by some change in another substance which may be called "Y." This also may differ from star to star. In order to keep the star at maximum for months and years at a time, X must be produced from Y at a uniform or nearly uniform rate. Furthermore, it is necessary that X be more active at low than at high pressures; and that Y can be produced in the R Coronae stars only under the conditions prevailing at minimum light.

Under these assumptions, an R Coronae star, after spending sometime at maximum light, would reach a state where the supply of Y would be insufficient to renew the supply of X. After a few days, there would be a shortage of X; radiation could not be kept up and the star would collapse. If X furnished, say, nine-tenths of the energy supply, the collapse, which would result in higher density and pressure in the star's interior, would so cut down the supply of energy by cutting down the activity of X, that the star would still be out of equilibrium and the collapse would continue until a point was reached where the radiation was equal to the available energy. This point would be at the minimum luminosity of the star. In collapsing, the star would leave a gaseous envelope, of a thickness comparable to the star's radius at minimum light and giving a bright line spectrum.

Having reached minimum, the star would begin to form and store Y in its interior, perhaps not immediately, if Y were the product of a chain of reactions or

atomic changes. As soon as formed, some of the Y would turn into X. After a time, there would be enough X to radiate an appreciable amount of energy. The star would be out of equilibrium again. It would start to expand. This would bring the X into action more effectively than before. The star would expand still more. It would keep on expanding, until it reached the point where the luminosity caught up with the increased efficiency of the X. It might have two or three temporary stillstands, on its rise to maximum if the supply of X at the beginning of the rise was not great enough to carry it to maximum. At each stillstand, however, Y would be turning into X faster than X was being destroyed, so the star would resume its climb towards maximum in time.

Maximum light in the R Coronae stars is probably the point of equilibrium between the production and the destruction of X. It is also the point of greatest efficiency for the release of energy from X. If the greatest speed of disintegration of X came at a point brighter than the point where the amount of X is in equilibrium, then at every cycle of light variation the star would rise to a sharp maximum and start to fade almost immediately. T Orionis has such a light curve. If the equilibrium point and the point of fastest release of energy from X were very near each other the typical R Coronae light curve, with its flat nearly constant maximum would result. The same results occur when the point of greatest efficiency of X is on the faint side of the equilibrium point.

In the case of those R Coronae stars with excess of carbon, the most probable candidate for X is the Boron isotope of atomic weight 12. This would give off beta rays, producing carbon. The carbon, while the star is at minimum is probably built up into N^{16}, which gives off an alpha particle, producing B^{12}. At the higher pressures and densities prevailing at minimum, the B^{12} is synthesized into heavier elements before it can disintegrate. But at and near maximum it can disintegrate before it is transformed.

In the case of the variables where like XX Ophiuchi and Z Canis Majoris, iron dominates the spectrum, "Atkinson's metal," Zinc of atomic weight 60, is probably serving as X, and Germanium of atomic weight 64 as Y. Then the mechanism is roughly as follows: The Ge^{64} expels an alpha-particle, becoming Zn^{60}. This expels another alpha-particle, becoming Ni^{56}, which absorbs two electrons and becomes Fe^{56}. At minimum light, Fe^{56} is built up into Ge^{64}, the disintegration of the Zn^{60} being smothered.

These two above theories are those provisional hypotheses which seem to be best suited to the situations in the present state of the writer's knowledge. In fact this whole paper is intended more as a guide to further investigations than as an authoritative interpretation.

Some questions bearing on the causes of R Coronae variation which might be investigated are:

The photographic light curves.
The way in which the color index changes during the light cycle.
The spectroscopic absolute magnitudes of the variables.
The variations of spectrum and radial velocity during the light cycle.
The radiometric magnitudes of some of the brighter stars of the class.
The proper motions and radial velocities of the variables.

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Christine, North Dakota, October 8, 1936.